A LONGITUDINAL STUDY OF THE STABILITY OF THE DENTITION FOLLOWING ORTHODONTIC TREATMENT

VOLUME 1

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DECLARATION

I hereby declare that this thesis entitled:

A longitudinal study of the stability of the dentition following orthodontic treatment,

is my own work, and has not previously in its entirety or in part been submitted at any university for another degree by myself.

Signed.

Date:

The greatest gift is the passion for reading. It is cheap, it consoles, it distracts, it excites, it gives you knowledge of the world and experience of a wide kind. It is a moral illumination.

--- Elizabeth Hardwick.

DEDICATION

This thesis is dedicated firstly to my wife **HEIDE**, and children **CHARL**, **PATRIC** and **AILEEN** who patiently supported and encouraged me to achieve this important milestone in my career, and to my father-in-law, DR G.J.J. **WATERMEYER**, who tremendously influenced my orthodontic career by his positive support and encouragement.

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They co-operated willingly and their contribution made this study possible.

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SUMMARY

The maintenance of dental alignment following orthodontic treatment has been, and continues to be, a challenge for the orthodontist (McReynolds and Little, 1991). Orthodontists should endeavour to establish normal occlusions and function to the end that physiologic balance and retentive stability may be achieved (Goldstein, 1953). Many philosophies and theories have been formulated in response to this challenge, but few have successfully withstood the test of rigorous post-orthodontic evaluation.

The present study comprises longitudinal assessments of dentofacial changes which occurred in South African Caucasian subjects during their orthodontic treatment as well as a mean of 7 years following active treatment. The sample consists of 88 Caucasian subjects; 33 males and 55 female subjects who have undergone conventional edgewise orthodontic treatment (Lindquist, 1985). The treatment includes extraction (56%) and nonextraction (44%) therapy.

Due to the intricate structure of the craniofacial complex, it is deemed important to discuss the major components of this complex separately and then to compare the variables describing the area with post-orthodontic lower incisor crowding. Lower incisor crowding or irregularity, most often referred to as relapse when occurring in the post-orthodontic dentition, is a phenomenon that is

clinically visible and easily assessed using the Little Irregularity Index (Little, 1975). A variety of orthodontic study cast and cephalometric variables represent the changes which occur at the three time intervals selected for this study, namely pre-treatment (T1), post-treatment (T2) and following active treatment (T3). Statistical analysis of the data was undertaken by the Institute for Biostatistics of the Medical Research Council, Tygerberg, RSA utilising the SAS (1985). The significance level of the results of this study is set at p = 0.05.

No previous study has documented the literature or has evaluated and described the various parts of the craniofacial skeleton in this format.

The thesis is divided into thirteen chapters.

CHAPTER 1: INTRODUCTION

Chapter 1 is a general introduction to this longitudinal study, documenting relevant literature and stating the all-encompassing purpose of the study which was to record the changes occurring in the dentition during and following orthodontic treatment, and to evaluate certain parts of the craniofacial skeleton and soft tissue profile in respect to stability of the post-orthodontic occlusion.

CHAPTER 2: TERMINOLOGY

Chapter 2 lists and defines various terms which have been used in the literature to describe post-treatment changes in the dentition. This is necessary in view of the widely held opinion that all post-treatment changes are referred to as relapse of orthodontic treatment. The immediate understanding of this terminology is that of a badly treated occlusion, but not all post-treatment changes are within the orthodontist's control. Hence the introduction of terms such as "rebound" and "physiologic settling".

CHAPTER 3: MATERIALS AND METHODS

In comparison to other studies described in the literature, the present study examines one of the largest longitudinal samples. Various other professed elite studies in the world used smaller samples. These studies are referred to in this thesis. No other study has evaluated so many parameters in such an encompassing manner as the present study. When undertaking a study of this nature one has to plan to compare the data and the conclusions with other studies in this regard. Therefore, similar methods as described in the literature were used to compile the data of the present study. A combination of the best methods described are utilised, a procedure not yet previously applied.

The materials and methods utilised during the study are described in Chapter 3. Each landmark and variable used is defined. Relevant figures support these descriptions.

The essence of the thesis is described in Chapters 4-12. Each chapter comprises a number of sections or subdivisions. An introductory discussion offers a literature review and ends with the statement of the objectives of that part of the study. Natural changes are included where applicable to give insight to those occurring not only in the untreated dentition, but also in the orthodontically treated dentition. The measurements are described, results are set out in tables, discussed and conclusions are drawn regarding the stability of the treated occlusion.

This study is unique in this regard as no other study has evaluated or described relapse and stability in this manner.

CHAPTER 4: NASOMAXILLARY COMPLEX

The nasomaxillary complex which is attached to the cranial base via sutures, is described and discussed in this chapter. It is apparent that care must be exercised when distalizing the maxilla as this retrusive displacement could influence the post-orthodontic stability of the lower incisor teeth. This is especially true when concommitant forward growth of the mandible is occurring.

CHAPTER 5: MANDIBLE

The mandible and its relationship to post-orthodontic lower incisor irregularity are described and discussed in Chapter 5. The forward growth and closing rotation of the mandible, also experienced in the untreated individual, can influence the alignment of the lower incisor teeth.

CHAPTER 6: ANTEROPOSTERIOR DIMENSION

The anteroposterior dimension, as described and discussed in this chapter, forms an integral part of the orthodontic evaluation. Malocclusions have been classified according to this dimension since the late nineteenth century (Angle, 1899). In the sample under study, the well-known ANB angle was found to record a consistent decrease through the period under review. The post-treatment changes of this angle are mostly growth related and in particular to growth of the mandible. The dental arch length shows a continual decrease in size. It is obvious that these decreases must influence the anterior dental alignment detrimentally.

CHAPTER 7: OCCLUSION

The goal of every orthodontist is to achieve a functional and stable post-treatment occlusion. The static and functional ideals are described in this chapter. An example of a significant conclusion is that the arch dimensions should be kept unaltered throughout treatment. During the post-orthodontic period, the intercanine width decreased to a value smaller than the original value. This is similar to changes occurring in untreated dentitions. Such decreases could play a role in post-treatment relapse.

Numerous occlusal variables are studied in respect of their changes during the various time intervals. The reader is referred to the particular text for the relevant detail.

CHAPTER 8: ANTERIOR BORDER OF THE DENTITION

In Chapter 8 the longitudinal changes are described of the anterior border of the dentition. Cephalometric norm values published in the literature are taken as acceptable clinical goals. The stability of the post-orthodontic dentition of this study, and especially the stability of the anterior alignment, can be ascribed to the achievement of these ideals.

CHAPTER 9: VERTICAL DIMENSION

Vertical control during treatment is essential as unwarranted opening or closing of the bite may result in relapse of a treated occlusion. The vertical changes are described and discussed in this chapter. The vertical dimensions of the treated subjects in this study were not significantly altered during treatment. This effective control contributed to the stability of the treated dentition as is shown by the stable overbite measurement recorded during the post-orthodontic period. Other studies reported an increase in the overbite during the post-orthodontic interval.

CHAPTER 10: EXTRACTION VERSUS NONEXTRACTION TREATMENT

Extraction treatment has been controversial since the introduction of orthodontic therapy. The extraction of teeth does not necessarily guarantee stability of lower incisor alignment. In this study no significant difference is shown between the extraction and nonextraction groups regarding post-treatment lower incisor crowding when the pooled male and female sample is evaluated. This is in accordance with other studies reported in the literature. There is, however, a difference when the males and females are separately assessed as noted in Chapter 12. This factor must be seriously taken in consideration when planning the treatment of a malocclusion.

CHAPTER 11: SOFT TISSUE PROFILE

Many orthodontists assess the excellence of their treatment only by the achievement of a sound soft tissue profile. This confirms its importance in orthodontics. The soft tissue changes are extensively discussed in Chapter 11. It is largely growth and maturity changes which occur post-treatment. The lower third of the soft tissue profile becomes more retrusive during this time. This profile change occurs simultaneously with the forward growth of the mandible as well as the lower incisor uprighting during the post-treatment period. All these changes could influence the post-orthodontic lower incisor alignment.

CHAPTER 12: SEXUAL DIMORPHISM

A longitudinal evaluation of the orthodontically treated dentition is not complete without assessing sexual dimorphism. These differences are described and discussed in Chapter 12. Dimensional differences recorded in this study are similar to those described in the literature with the males showing the larger dimensions. Males have more retrusive lips relative to the various profile lines. It is reported that extraction and nonextraction treatment ultimately end with the same amount of relapse. The present study reports the contrary. The female sample shows better maintenance of post-orthodontic lower incisor alignment. It is also within the female sample that a larger percentage of extractions were performed during orthodontic treatment.

CHAPTER 13: GENERAL DISCUSSION AND CONCLUSIONS

A general discussion, and conclusions are presented in this chapter. Although many authors have reported the importance of the lower incisor position, it was shown in the present study that the maxillary incisor position is as important in respect to long-term stability of the treated occlusion. Growth, especially post-pubertal mandibular growth, appears to play a major role in the changes of the post-orthodontic dentition. The excecution of a well-founded treatment plan and the control of the facial dimensions and tooth positions as part of a sound orthodontic technique seem to be important in the achievement of a stable result.

OPSOMMING

Die instandhouding van tandbelyning na voltooiing van ortodontiese behandeling was en sal nog steeds in die toekoms 'n uitdaging bied vir ortodontiste (McReynolds en Little, 1991). Die ortodontis se strewe moet wees om 'n normale okklusie in die ortodontiese pasiënt te vestig, waartydens die funksie van die kake herstel word, asook fisiologiese harmonie en stabiliteit van die okklusie gevestig word (Goldstein, 1953). Menige filosofieë en teorieë is al voorgestel om hierdie doelwitte te kan bereik, maar baie min het nog daarin geslaag.

Tydens die huidige longitudinale studie is gepoog om 'n ondersoek te doen van die veranderinge wat plaasvind in die dentofasiale omgewing van agt-en-tagtig Suid-Afrikaanse Kaukasiese pasiënte tydens hulle ortodontiese behandeling, asook na die verloop van 'n gemiddeld van sewe jaar sedert die behandeling voltooi was. Die monster het uit 33 manlike en 55 vroulike pasiënte bestaan wat met 'n konvensionele vierkantsdraad ("edgewise") ortodontiese tegniek behandel was (Lindquist, 1985). Die behandeling het 56% ekstraksie en 44% nie-ekstraksie behandelingsbeplannings ingesluit.

Weens die baie komplekse kraniofasiale omgewing is dit besluit om elke deel waaruit hierdie omgewing bestaan, afsonderlik te beskryf en te bespreek. Die veranderlikes wat

elke deel beskryf is vervolgens gekorreleer met die na-behandelings ondersnytand-bondeling. Ondersnytand-bondeling is 'n verskynsel wat klinies sigbaar is en meestal na verwys word as terugval indien dit voorkom in die na-behandelings resultaat. Dit kan maklik gemeet word met behulp van die "Little Irregularity Index" (Little, 1975). 'n Verskeidenheid van ortodontiese studiemodelle en kefalometriese veranderlikes is tydens die voor-behandelings (T1), na-behandelings (T2) asook na verloop van 'n gemiddeld van sewe jaar na afhandeling van die behandeling (T3) gemeet. Die statistiese verwerkinge is deur die Instituut vir Biostatistiek van die Mediese Navorsingsraad, Tygerberg, R.S.A. gedoen deur middel van die SAS (1985). Die betekenisvolheidsperk van die studie is op p = 0.05 gestel.

Geen studie het al voorheen die literatuur en die gedefineerde areas van die kranio-fasiale skelet in hierdie formaat ondersoek of beskryf nie.

Die proefskrif bestaan uit dertien hoofstukke.

HOOFSTUK 1: INLEIDING

In Hoofstuk 1 word 'n algemene inleiding gegee tot hierdie longitudinale studie, waartydens die relevante literatuur aangehaal word en die doelwit van die studie gestel word. Die doelwit is om die veranderinge te bestudeer en te beskryf wat plaasvind in die kranio-fasiale skelet en sagteweefsel profiel tydens en na voltooiing van ortodontiese behandeling, asook hulle verband met langtermyn stabiliteit van die okklusie aan te dui.

Die oorkoepelende doelwit, naamlik om vas te stel watter faktore die na-behandelings okklusie laat terugval en watter faktore die behandeling stabiel laat bly, is soortgelyk aan studies wat in hierdie verband gedoen is. Sekere van hierdie studies het optimistiese en ander negatiewe gevolgtrekkings gemaak ten opsite van ortodontiese behandeling en veral die na-behandelings resultate. Weens hierdie uiteenlopende gevolgtrekkings bly dit dus belangrik om voort te soek na data wat een van hierdie weë ondersteun, asook na parameters wat nog nie voorheen vergelyk is met terugval nie. In hierdie opsig is die huidige studie uniek, want geen studie is egter nog in soveel detail bespreek en beskryf nie. Daar is ook nog nie voorheen op een tydstip na al die verskillende parameters soos in die huidige studie gemeet en beskryf is, verwys nie.

<u>HOOFSTUK 2: TERMINOLOGIE</u>

In hoofstuk 2 is verskeie terme wat in die literatuur gebruik word om na-behandelings veranderinge te beskryf, gedefinieer. Dit is nodig geag aangesien die algemene aanname is dat na-behandelings veranderinge terugval is of dat dit dan, in die algemeen gesien, na verwys word as onsuksesvolle behandeling. Alle na-behandelings veranderinge kan egter nie deur die ortodontis beheer word nie, vandaar die verwysing na terme soos die terugspring en die fisiologiese insok van tande.

HOOFSTUK 3: MATERIALE EN METODES

Tydens hierdie studie word in vergelyking met andere in die literatuur beskryf, een van die grootste monsters longitudinaal ondersoek. Verskeie van die sogenaamde vooraanstaande studies in die wêreld en wat volledig aangehaal is in die proefskrif, het kleiner monsters gebruik. Meer veranderlikes is nog nie gesamentlik tevore in hierdie vorm ondersoek nie. Om die data en die gevolgtrekkings van die huidige studie sinvol te kan vergelyk met ander studies in die verband, moes soortgelyke meetmetodes, soos in die literatuur beskryf, gebruik word. 'n Kombinasie van die beste metodes is gebruik, 'n prosedure wat nog nie voorheen aangewend is nie.

Die materiale en metodes wat tydens die studie gebruik is, word in Hoofstuk 3 beskryf. Elke landmerk en veranderlike gebruik se beskrywing is met figure ondersteun.

In Hoofstukke 4 tot 12 is die grondbestandele van die proefskrif beskryf. Elke hoofstuk bestaan uit 'n aantal afdelings. Die inleiding bestaan hoofsaaklik uit die literatuur oorsig en eindig met die stelling van die doelwit van die deel van die studie. Natuurlike veranderinge is ook ingesluit, waar toepaslik, aangesien dit insig gee ten opsigte van die verhouding daarvan in behandelde en onbehandelde pasiënte. Die verskillende metings van die veranderlikes is beskryf, die resultate is in tabelle uiteengesit, die resultate is bespreek en verskeie gevolgtrekkings is gemaak ten opsigte van die stabiliteit van die okklusie.

Hierdie studie is uniek in die verband aangesien nog geen studie terugval en stabiliteit van ortodontiese behandeling in hierdie formaat ondersoek en beskryf het nie.

HOOFSTUK 4: NASOMAKSILLÊRE KOMPLEKS

Die kompleks, wat deur middel van nate aan die kraniale basis geheg is, is in hierdie hoofstuk beskryf en bespreek. Versigtigheid moet aan die dag gelê word wanneer die maksilla deur middel van die ortodontiese behandeling distaal beweeg word, aangesien hierdie beweging die stabiliteit van die ondersnytande kan beïnvloed. Dit is veral belangrik indien die voorwaartse groei van die onderkaak ook in ag geneem word.

HOOFSTUK 5: MANDIBULA

Die mandibula en sy verhouding met die na-behandelings ondersnytand-bondeling is beskryf en bespreek in hierdie hoofstuk. Die voorwaartse en anti-kloksgewyse groeibeweging van die onderkaak, soos ook waargeneem in die onbehandelde individu, beïnvloed die na-behandelings ondersnytand belyning.

HOOFSTUK 6: ANTERO-POSTERIOR VERHOUDING

Hierdie verhouding, soos beskryf en bespreek in die hoofstuk, maak 'n belangrike deel uit van die ortodontiese evaluering. Wanokklusies word al sedert die laat negentiende eeu (Angle, 1899) geklassifiseer. Die ANB hoek, een van die hulpmiddels nodig vir die skeletale klassifikasie van 'n individu, het gedurende die projek afname in waarde getoon. Hierdie verandering is nou gekoppel aan groei en in die besonder aan dié van die onderkaak. Die booglengte van die tandboog vertoon ook aanhoudende afname in waarde. Hierdie veranderinge kan die ondersnytand belyning nadelig beïnvloed.

HOOFSTUK 7: OKKLUSIE

Die doelwit van elke ortodontis is om toe te sien dat 'n funksionele en stabiele na-behandelings okklusie gevestig word. Die statiese en funksionele doelwitte is in hierdie hoofstuk beskryf. Voorbeelde van betekenisvolle gevolgtrekkings is:

i) tandboog dimensies moet so min as moontlik verander word tydens behandeling, want veranderlikes soos die inter-hoektand wydte verminder in die na-behandelings periode na waardes minder as die oorspronklike afmetings.

ii) molaar en hoektand verhoudings bly stabiel nadat behandeling voltooi is.

Hierdie gewaarwordinge is soortgelyk aan dié wat plaasvind in die onbehandelde gevalle en speel sekerlik 'n rol in die na-behandelings stabiliteit van die ondersnytand belyning. Verskeie ander okklusale metings is geneem gedurende die studie. Die leser word na die inhoud van die hoofstuk verwys vir die relevante detail.

HOOFSTUK 8: ANTERIOR GRENS VAN DIE TANDBOë

In Hoofstuk 8 is die longitudinale veranderinge van die anterior grens van die tande beskryf. Kefalometriese standaardwaardes is in die literatuur te vind en hierdie norme is steeds klinies bruikbaar. Die stabiliteit van die okklusie in hierdie studie, en veral die anterior tand-belyning, kan toegeskryf word aan die bereiking van hierdie kefalometriese doelwitte.

HOOFSTUK 9: VERTIKALE VERHOUDING

Vertikale beheer tydens ortodontiese behandeling is belangrik aangesien hierdie verhouding vergroot kan word tydens behandeling. Die na-behandelings neiging is vir hierdie vertikale verhouding om te verklein. So 'n verandering sal lei tot die bondeling van die ondersnytande. Die vertikale afmetinge is nie betekenisvol verander tydens die behandeling van die individu nie en het bygedra tot, onder andere, die stabiele oorbyt. Ander bekende studies beskryf 'n verdieping van die oorbyt na verloop van tyd. Die vertikale veranderlikes is beskryf en bespreek in Hoofstuk 9.

HOOFSTUK 10: EKSTRAKSIE EN NIE-EKSTRAKSIE BEHANDELING

Ekstraksie behandeling is steeds 'n kontroversiële onderwerp. Die ekstraksie van tande as deel van ortodontiese behandeling verseker nie noodwendig 'n stabiele resultaat nie. Geen betekenisvolle veranderinge is aangetoon, tussen ekstraksie en nie-ekstraksie groepe in terme van die na-behandelings ondersnytand bondeling, waar die geslagte gesamentlik beskou is nie. Hierdie gevolgtrekking ondersteun die resultate van ander studies. Daar is egter wel 'n betekenisvolle verskil in laasgenoemde verhoudings getoon wanneer die geslagte afsonderlik evalueer word en die belangrike bydrae in hierdie verband moet in ag geneem word tydens behandelingsbeplanning.

HOOFSTUK 11: SAGTE WEEFSEL PROFIEL

Baie ortodontiste meet hulle sukses aan die bereiking van 'n estetiese sagte-weefsel profiel wat die belangrikheid van hierdie veranderlike beklemtoon. Die sagte weefsel veranderinge is in Hoofstuk 11 beskryf en bespreek. Dit is hoofsaaklik na-behandelings groei en maturasie-veranderinge wat die ondernytand belyning beïnvloed. Die onderste een derde van die sagte weefsel profiel word meer konkaaf as gevolg van die voorwaartse groei van die onderkaak. Beide hierdie laasgenoemde veranderinge kan na-behandelings ondersnytand bondeling veroorsaak.

HOOFSTUK 12: GESLAGSVERSKILLE

'n Longitudinale evaluasie van die ortodonties-behandelde gebit is nie volledig indien die geslagsverskille nie beskryf en bepreek word nie. Hierdie verskille is in Hoofstuk 12 gedokumenteer. Mans vertoon groter dimensies wat in ooreenstemming is met verslae wat in die literatuur gepubliseer is. Mans het meer retrusiewe lippe gemeet ten opsigte van die verskillende profiel-lyne. Vroue het beter na-behandelings belyning van ondersnytande vertoon. Dit is ook die vroulike groep waarin meer ekstraksies deel van die behandeling uitgemaak het. Hierdie is in teenstelling met die huidige denke in die literatuur.

HOOFSTUK 13: ALGEMENE BESPREKING EN GEVOLGTREKKINGS

'n Algemene bespreking en gevolgtrekkings is te vind in Hoofstuk 13. Alhoewel baie outeurs die belang van die ondersnytand posisie beskryf, word dit in die huidige studie getoon dat die maksillêre snytand 'n ewe belangrike rol speel in die stabiliteit van die behandelde okklusie. Dit kom voor asof groei 'n belangrike oorsaak van na-behandelings veranderinge in die dentofasiale omgewing is. Die uitvoering van 'n goeddeurdagte behandelingsplan, en die beheer van gesigsdimensies, asook tandposisies as deel van 'n goeie ortodontiese tegniek, is belangrike eienskappe wat bydraes lewer tot 'n stabiele resultaat.

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CHAPTER 1

INTRODUCTION

1.1 General overview of longitudinal orthodontic changes

A great deal of research into craniofacial development is undertaken to provide a more complete understanding of those aspects which touch on the orthodontic profession. The need to obtain developmental and morphologic homeostasis has become one of the most significant challenges in orthodontics. Notwithstanding these research efforts, a workable concept which takes into account the complex circumstances dealing with equilibrium and stability, versus imbalance and relapse, are largely lacking. At the present time no mechanical instrument is available to determine or to predict the stability of a dentition. Although attempts in this regard have been reported in the literature, no method presently exists to predict accurately the future status of the post-treatment orthodontic occlusion (Lombardi, 1972; Peck and Peck, 1972a; Keene and Engel, 1979).

Orthodontists are largely committed to treatment excellence, not only because of ethical responsibilities, but also because the profession, in many ways, aims to improve the quality of life. Edward Hartley Angle (1899, 1907) defined a normal occlusion according to a number of criteria still in daily use. It was his belief that a normal occlusion required a full compliment of teeth. In response to Angle's work, Tweed (1944) proposed a philosophy of good orthodontic treatment. He stressed the principle of the lower incisors being positioned over mandibular basal bone. According to Tweed the objectives of orthodontic therapy viz. i) good facial aesthetics, ii) efficient masticatory function, iii) healthy investing tissues to assure longevity of the dentition and, iv) permanency of tooth position, required extractions in more than 50% of all orthodontically treated subjects (Tweed, 1944).

These principles have been elaborated on in a series of "classic" articles which proposed certain "keys of normal occlusion" (Andrews, 1972, 1976). In order to attain occlusal stability following orthodontic treatment and to limit the use of retainers, certain criteria must be met. These criteria focus on the position of the lower incisor and canine teeth (Williams, 1985). Failure to achieve the high standards demanded by the profession is not acceptable and leaves a feeling of personal defeat with the operator. Notwithstanding the real risk of failure, the challenge of providing excellent orthodontics should not be evaded (Little, 1990). The additional effort and commitment required to obtain the best possible end result goes with the territory. It is certainly satisfying to document and display those cases that remain excellent, despite the passage of time, as examples of our prowess and skill.

Quality orthodontics reflects well not only on the individual orthodontist, but on the profession in general. The sense of failure caused by well-treated occlusions which deteriorate with time can lead to feelings of frustration. Given the recognised problems associated with treatment, certain relapse changes may be anticipated. The original problems, unfavourable cooperation, and poor growth, are factors which may give a warning that relapse is a possibility. At other times relapse will occur unexpectedly and for no obvious reason.

Occlusal stability following orthodontic treatment should be considered to be a primary goal for every orthodontist (Sandusky, 1983). In the search for post-orthodontic treatment stability it may be necessary for an orthodontist to review his diagnosis, change his treatment regime, or even to vary his overall treatment philosophy. The ability to recognise weaknesses in orthodontic diagnosis and treatment, and to adapt treatment modalities to improve occlusal function, facial aesthetics, long-term dental health and stability of treatment results is an integral part of the profession of orthodontics.

The quest to understand the fine balance which exists between stability and relapse has led to many attempts to identify some significant factor(s) which are responsible for post-treatment relapse (Sanin and Savara, 1973; Siatkowski, 1974; Little, Wallen and Riedel, 1981; Owman, Bjerklin and Kurol, 1989). Every time an orthodontist treats a malocclusion it is assumed that the odds will favour success. The possibility of failure is, however, very real. There are many pitfalls which lead to treatment problems and no orthodontist is immune to them (Strang, 1954). It is important that clinicians learn from their mistakes and in that respect they should from the outset assume that stability is not always achievable (Rubin,1988).

Fortunately, endeavours to improve knowledge and treatment methods in orthodontics have resulted in many excellent investigations into aspects of relapse (Sadowsky and Sakols, 1982; Sandusky, 1983; Little, 1990). Despite these important studies many causes of orthodontic relapse are not fully understood (King, 1974). The following statements are frequently made: "because the bite was deep to start with, it is likely to relapse"; "overbite relapses significantly following correction"; "everything is Class I now, but the buccal segments will probably slip" (Bresonis and Grewe, 1974). The question arises whether these somewhat pessimistic statements are based on sound facts?

It has been said, "Knowledge is what you learn from others; wisdom is what you teach yourself." It is not such a tragic fault to make a mistake for the first time. It is, however, tragic to repeat the same mistake time and again. The present study arose out of a desire to eliminate mistakes which prejudice against long-term stability following orthodontic treatment.

1.2 Objectives of the present study

The main purpose of the present study was to identify those factors which contribute to post-orthodontic treatment relapse. In general this does not differ from other studies which were conducted on this subject, but no other study has however been reported which documents its objectives in such an encompassing manner as the present study. The present study is unique in the sense that objectives are set not only to try to confirm the results of other studies, but also to evaluate the different areas of the craniofacial skeleton in a variety of combinations with the purpose of attempting to show whether new knowledge could be added to the field of stability of the post-treated occlusion. Stability of treated occlusions is the ultimate goal which every orthodontist strives to achieve. Some reports in the literature seem to make this a very elusive target and others seem to be more optimistic. It is thus important to keep on searching for those factors which are responsible for changes in the post-orthodontic occlusion and also to identify those factors which will contribute to long-term stability.

The craniofacial skeleton is divided into several areas which are covered by soft tissues. In order to identify the causes of post-orthodontic treatment relapse, it was deemed necessary to study specific craniofacial areas and their relationships to post-treatment relapse with specific reference to lower incisor crowding. The objectives of the present study were thus to assess and record pre-, and post-orthodontic treatment changes in:

a) the nasomaxillary complex,
b) the mandible,
c) the relationship of the maxilla to the mandible,
d) the occlusion,
e) the anterior border of the dentition,
f) the vertical dimensions of the face,
g) the soft tissue of the facial profile,
h) the extraction and nonextraction groups, and
i) the pooled and separated male and female sample (this was deemed essential as reports in the literature reflect both).

Clinically, most complaints are normally in respect to crowding of the mandibular incisors as this is visible to patients. Other changes do occur, but are not as visible. Therefore, the longitudinal changes in the abovementioned areas were examined in relation to post-treatment lower incisor imbrication. The aim was to establish correlations between the variables which described the different areas evaluated and the lower incisor irregularity.

Some of the abovementioned areas have been described individually in orthodontic literature, a few have also been described in combination, but nowhere are the objectives of a study in respect to the longitudinal changes in the occlusion of the orthodontic subject described in such detailed format. The uniqueness of the present study is reiterated by the manner in which the objectives are achieved and documented in the various chapters.

It is hoped that the insight gained from this study will not only assist orthodontists in their search for excellence in treatment and post-treatment stability, but that it will also complement the various other studies which have been done in this important facet of orthodontics.

1.3 Presentation of the thesis

Following the introductory chapter, a variety of terms which have been cited in the literature to describe post-treatment changes are discussed (Chapter 2). An account is given of the sample used in this study including details pertaining to sexual dimorphism, age distribution and whether extractions were performed as part of the orthodontic treatment provided (Chapter 3). A description is given of the methods and techniques used in the present study. The latter are discussed under two headings:

A. Metrical techniques and data gathering.

B. Statistical methods.

Chapters four to eleven are used to discuss the relationships between the longitudinal changes in the various craniofacial dimensions and post-treatment stability. This format has not previously been documented.

The final chapters encompass a general discussion, a referral to retention and a compilation of the conclusions.

The list of references cited is arranged alphabetically and chronologically.

CHAPTER 2

TERMS USED TO DESCRIBE POST-ORTHODONTIC TREATMENT CHANGES IN THE DENTITION

The choice of a term to describe the changes which may occur in a dentition following orthodontic treatment has received a fair amount of attention in the literature. Hellman (1944) distinguised between failure (operator-incompetence) and/or factors outside the control of an operator and relapse (changes in succesfully treated dentitions). Horowitz and Hixon (1969) used the term relapse to describe detrimental changes which occur following active orthodontic treatment.

There are many factors which may influence treated, as well as untreated occlusions. The same terms are used to describe the changes which can occur in both situations. The question may thus be asked: "How clearly are the terms relapse and failure really defined?". Theoretically and practically it is important to distinguish between these two entities as post-treatment and "aging" changes can be due to one or more aetiologic factors (Moyers, 1988; Proffit, 1986). Objective examination in order to determine the exact aetiologic factor is extremely difficult. The literature in respect of terms describing relapse is incomplete (Dermaut, 1974). Hence it was thus deemed necessary to define some of those terms here.

i) Relapse,
ii) Physiologic recovery,
iii) Developmental changes,
iv) Rebound,
v) Post-retention settling,
vi) "Recidief",
vii) Crowding,
viii) Recrowding and
ix) Imbrication.

2.1 Relapse

Relapse is the return to a former condition, especially after improvement or seeming improvement. Riedel (1976) believes that the word is too harsh a description of the changes that follow orthodontic treatment and he prefers the term "post-treatment adjustment" for these changes. A mutiplicity of factors cause post-treatment adjustment.

The Shorter Oxford English Dictionary (1975) defines relapse as follows : "to fall back into or to revert to a former habit or state, a falling back into error, heresy or wrong-doing; back-sliding; the fact of falling back again into an illness after a partial recovery".

Horowitz and Hixon (1969) define relapse in general as changes in tooth position after orthodontic treatment. They do also mention that these changes can take place even though no treatment was instigated. It is thus necessary to distinguish between relapse, physiologic recovery and developmental changes.

2.2 Physiologic recovery

Physiologic recovery is a return to a normal condition which is characteristic of normal functioning living organisms. Horowitz and Hixon (1969) explain physiologic recovery as the change to the original physiologic state after completing treatment.

2.3 Developmental changes

Developmental changes are those which occur irrespective of whether orthodontic treatment was implemented or not. These changes could easily be overlooked when assessing post-treatment relapse. The developmental changes occuring in subjects who have not undergone any orthodontic treatment are well documented in the literature (Riolo, Moyers, McNamara and Hunter, 1974; Broadbent, Broadbent and Golden, 1975; Moyers, van der Linden, Riolo and McNamara, 1976; Sinclair and Little, 1983, 1985).

2.4 Rebound

To spring or bounce back after hitting or colliding with something; a recoil. This phenomenon can be ascribed to the elasticity of tissues. The retraction of the upper incisors can be responsible for a variety of changes in the morphology of the upper lip. The upper lip may become more retrusive in the absence of lip strain, when the lip is thin or in adult subjects. The opposite effect is also possible, resulting in no lip retraction or in the upper lip becoming more protrusive. The upper lip and upper incisors are thus of key-importance when deciding on a treatment plan. In planning a soft tissue visual treatment objective the rebound of the upper lip, during the post-orthodontic period, should be taken into account when the upper incisor position is determined (Holdaway, 1984).

2.5 Post-retention settling

Settling can be described as the establishment of a desired position. It leads to the arrangement of the teeth in a final or satisfactory form which may be of more or less permanent or of an unvarying configuration. The teeth "sink" into occlusion and thus become comfortably adapted to a new environment or situation. Retention appliances should preferably be passive devices which allow the teeth to settle into their final positions during function. In this way post-retention settling will be maximized.

2.6 "Recidief"

Recidivism is described in The Shorter Oxford English Dictionary (1975) as "a tendency to relapse into a former pattern of behaviour". The concept is more applicable to behavioural patterns; for example a tendency to return to criminal habits as is defined in the above dictionary. The term "recidief" has been used to describe changes which occur from the end of treatment back to the original situation (Dermaut, 1974).

2.7 Crowding or recrowding

Crowding means to force tightly together. Lower incisor crowding (recrowding) is normally the main problem noted in a post-orthodontic evaluation. Crowding as a result of post-treatment changes were fully described by Little (1975, 1990).

2.8 Imbrication

Imbrication refers to a regular overlapping of edges often seen as with tiles on a roof or the scales of a fish. This overlap is often used to describe incisor irregularity or crowding whether seen pre- or post-treatment.

Two other terms used in respect of relapse are stability and retention.

2.9 Stability

The Shorter Oxford English Dictionary (1975) defines stability as "the condition of maintaining equilibrium". This refers to the quality or condition of being stable; the fixity of position in space or the capacity for resistance to displacement. Some orthodontists may be reluctant to evaluate their patients in the post-retention phase of treatment. It is, however, only through a retrospective view of treatment that factors which cause undesirable post-retention changes can be identified. Such discoveries could lead to greater occlusal stability following orthodontic treatment.

2.10 Retention

Stability is not retention. Joondeph and Riedel (1985) explain retention as "the holding of teeth in ideal aesthetic and functional positions". Retention is accomplished by a variety of mechanical appliances.

Retention is defined in The Shorter Oxford English Dictionary (1975) as "the action or fact of holding or keeping in a place or position; retaining in a fixed position; the condition of being retained, the capacity to remember".

CHAPTER 3

MATERIALS AND METHODS

3.1 Sample description

A longitudinal study is a tedious undertaking which tests the patience of all involved. One of the goals of such a study is to use the largest sample possible which would statistically provide accurate and representative results. Numerous factors impede the achievement of this feat. Longitudinal studies in respect to long-term stability and with varying sample size have been reported. Some of the more recent studies are as follows (sample size and minimum post-retention interval in parentheses):

i) Simons and Joondeph (1973) (70, 10 years).
ii) Shapiro (1974) (80, 10 years).
iii) Gardner and Chaconas (1976) (103, ±5 years).
iv) El-Mangoury (1979) (50, 2 years).
v) Little, Wallen and Riedel (1981) (65, 10 years).
vi) Sadowsky and Sakols (1982) (96, ±20 years).
vii) Uhde, Sadowsky and BeGole (1983) (72, ±20 years).
viii) Shields, Little and Chapko (1985) (54, 10 years).
ix) Glen, Sinclair and Alexander (1987) (28, 3 years).
x) Little, Riedel and Artun (1988) (31, 10-20 years).

The original sample of this study consisted of 102 Caucasian subjects who had undergone conventional edgewise orthodontic therapy followed by varying periods of retention and eventual removal of all retention. A decrease in the sample size occurred in order to make the starting ages of the subjects, who had undergone orthodontic treatment, more uniform. The final sample of the study thus consisted of 88 subjects, including extraction and nonextraction groups of both sexes. The edgewise arch mechanism was Edward H. Angle's last and greatest contribution to orthodontics, after almost a lifetime devoted to the development of orthodontic appliances (Angle, 1928). Lindquist (1985) gave an excellent description of the conventional edgewise appliance and its application in the treatment of malocclusions (In: Orthodontics. Current Principles and Practice; Graber and Swain, 1985).

The subjects included in the study were drawn from the private practices of qualified orthodontists and from a University Dental School clinic where post-graduate orthodontic students treated patients under the supervision of these orthodontists in their capacity as part-time lecturers. The distribution of subjects amongst the abovementioned clinicians were as follows:

Practice 1 - 13.63%

Practice 2 - 7.96%

Practice 3 - 2.27%

Practice 4 - 2.27%

Practice 5 - 56.82%

University - 17.05%

Orthodontic plaster casts and cephalograms representing three stages of treatment, being pre-treatment (T1), post-treatment (T2) and a mean of 7-years (6.73 years, range 5.09 - 10.70 years) post-treatment (T3), were analysed. The active treatment period (T1-T2) involved the wearing of fixed orthodontic appliances for a mean period of 2.82 years. The post-orthodontic period (T2-T3) included the period during which the subjects were instructed to wear retention appliances. The mean post-retention period (no appliances present) was 5-years (4.90 years, range 0.08 - 17.17 years). During the retention period four subjects used prefinishers, two subjects had no retention appliances fitted and the remaining subjects had a maxillary Hawley appliance and fixed lower intercanine retention. The records of the subjects used were randomly selected from those of some 3000 patients. The quality of the post-treatment result did not influence their inclusion in the study. Only subjects with complete initial and final records could be included in the study. Practical problems such as inability to reach subjects many years after active treatment eliminated them from the study.

The sample included Angle Class I (27.3%), Class II (70.4%) and Class III (2.3%) malocclusions. The sample was also evaluated according to the skeletal classification using:

i) the angle ANB (Class I: 0.5 - 3.5 degrees; Class II: > 3.5 degrees; Class III: < 0.5 degrees) (Holdaway, 1956 describes an average of 2 degrees for Class I malocclusions),

ii) the Wits analysis (Jacobson, 1975), and

iii) the point A convexity (Ricketts, 1982).

The ANB and convexity correlate strongly when compared to each other (r = 0.94), but both correlate weakly with the Wits (r = 0.26 ANB, r = 0.27 convexity) (Nel, 1991). The skeletal classification gives an indication of the severity of the discrepancy between the anteroposterior positions of the maxilla and the mandible. The information obtained in this manner allowed for the exclusion of malocclusions treated by orthognathic surgery. Class III orthodontic mechanics are the opposite to that being used in the treatment of Class I and Class II malocclusions, but depending on the situation Class III elastics may be used in a Class II malocclusion and vice versa. It may also be asked why the inclusion of the Class III subjects in the sample (Table I). Malocclusions are normally classified according to the dental relationships (Angle, 1899; Dewey, 1942) and it was also done for the present sample. The two Angle Class III subjects included in the sample were classified by the Angle maxillary/mandibular first molar relationship (1899, 1907), but when assessing them in respect to the angle ANB, they showed angles of 5.01 and 5.68 degrees respectively. They were in fact Class II skeletal malocclusions, but possibly ended up with a Class III molar relationship as a consequence of molar drift. Four of the Angle Class I group showed skeletal Class III tendencies with angle ANB measuring -2.89, -1.11, -0.50 and 0.42 degrees respectively. It was deemed in order to include them in the sample. Only five Class II division 2 malocclusions were recorded as part of the sixty-two Class II malocclusions. The majority of the Class III subjects which were included during the random selection of the sample, were subsequently excluded as they were treated partly by orthognathic surgery.

It appears that the degree of difficulty of the malocclussions remain practically the same irrespective of which way the sample is classified. The comparison of the Angle molar and ANB classification for the present sample is represented in Table O.

No overt oral habits were present at the post-treatment follow-up assessment (T3).

A description of the sample is set out in Table I.

3.2 Orthodontic study model analysis

The static occlusal features of the three stages of treatment were evaluated through measurements made with a SYLVAC digital vernier caliper (Sylvac SA, Manufacturers of Precision Measuring Instruments, Rue du Jura 2, 1023 Crissier, Switzerland) with a resolution of 0,01 mm. The dimension of the different variables were measured on orthodontic study plaster casts of the pre-treatment, post-treatment and post-retention records of the sample. The points of the caliper were sharpened to permit access and to

TABLE O

A COMPARISON OF THE ANGLE DENTAL AND ANB SKELETAL CLASSIFICATION PARAMETERS

		ANB CLASSIFICATION			
		I	II	III	N
ANGLE MOLAR CLASSIFICATION	I	11	9	4	24
	II	12	50	0	62
	III	0	2	0	2
	N	23	61	4	88

N = Sample size
I = Class I
II = Class II
III = Class III

TABLE I

DESCRIPTION OF THE SAMPLE

SEX	Male(33)	Female(55)	
ANGLE CLASSIFICATION	Class I(24)	Class II(62)	Class III(2)
SKELETAL CLASSIFICATION (angle ANB)	Class I(23)	Class II(61)	Class III(4)
AGE (years)	T1 11,92 (range 10,10-14,20)		
	T2 1[illegible],74 (range 11,11-24,20)		
	T3 21,47 (range 16,20-33,50)		
EXTRACTION	Extraction(56%)	Nonextraction(44%)	

T1, T2 and T3 refer to the pre-treatment, post-treatment and post-treatment follow-up orthodontic evaluations respectively.

make measurements more accurate according to the methods suggested by Bolton (1958, 1962), Steadman (1961), Little (1975) and Sadowsky and Sakols (1982).

Dental impressions of the subjects (T3) were taken with impression alginate material and poured within one hour of gathering. A wax bite was also taken in centric occlusion. The individual sets of study casts of each stage of treatment of each patient were studied in occlusion as well as with the upper and lower models separated.

The following measurements were obtained by a single examiner (Table II):

3.2.1 Molar and canine relationships

The relationships for the left and right sides of each set of study models were recorded according to the system of Angle (1899, 1907). Less than a cusp deviation from a Class I relationship was regarded as being normal and given a score of zero (0) - ideal range. Deviations of a full cusp (edge-edge) or more than a full cusp (Class II or III) were given scores of 2 and 3 respectively.

Class I ideal molar and canine relationships are shown in figure 1.

TABLE II: DATA SHEET FOR RECORDING MEASUREMENTS DERIVED FROM DENTAL CASTS

NAME: .... **FILE NO:** ....

VARIABLE	SCORE(S)	PRE-TREATMENT	POST-TREATMENT	POST-ORTHODONTIC
MOLAR	0			
LEFT AND RIGHT	2			
	3			
CANINE	0			
LEFT AND RIGHT	2			
	3			
ANTERIOR OPENBITE				
NONE	0			
WITH OVERBITE	1			
0.0-3.0	2			
3.0+	3			
ANTERIOR CROSSBITE				
NONE	0			
1-2 TEETH	1			
3-4 TEETH	2			
OVERJET				
0.0-3.0mm	0			
3.5-6.0mm	2			
6.5-9.0mm	3			
9.5+ mm	4			
OVERBITE				
0.0-3.0mm	0			
3.5-5.0mm	2			
5.5+ mm	3			
POSTERIOR CROSSBITE				
NONE	0			
UNILATERAL	1			
BILATERAL	2			
MAXILLARY CROWDING				
0.0-3.0	0			
3.5-6.0	1			
6.5+ mm	2			
MANDIBULAR CROWDING				
0.0-3.0mm	0			
3.5-6.0mm	1			
6.5+ mm	2			
ROTATION				
0° - 15°	0			
15.5° - 90°	1			
90.5° - 135°	2			
135.5° - 180°	3			
CURVE OF SPEE				
0.0 - 1.5mm	0			
2.0 - 4.0mm	1			
4.5+ - mm	2			

LOWER INTERCANINE WIDTH
L3-3I
L3-3B

UPPER INTERMOLAR WIDTH
U6-6I
U6-6B

TOTAL MALOCLUSSION SCORE

BOLTON: Initial anterior .... posterior ....
Final

SPACE ANALYSIS

ARCH LENGTH

EXTRACTION

TEETH PRESENT

CLASSIFICATION

WISDOMS PRESENT Final

RETENTION APPLIANCES

11	/	21	41	/	31
12	/	22	42	/	32
13	/	23	43	/	33
14	/	24	44	/	34
15	/	25	45	/	35
16	/	26	46	/	36

ANTERIOR
POSTERIOR
SPACE ANALYSIS

LITTLE IRREGULARITY INDEX

LITTLE ARCH LENGTH

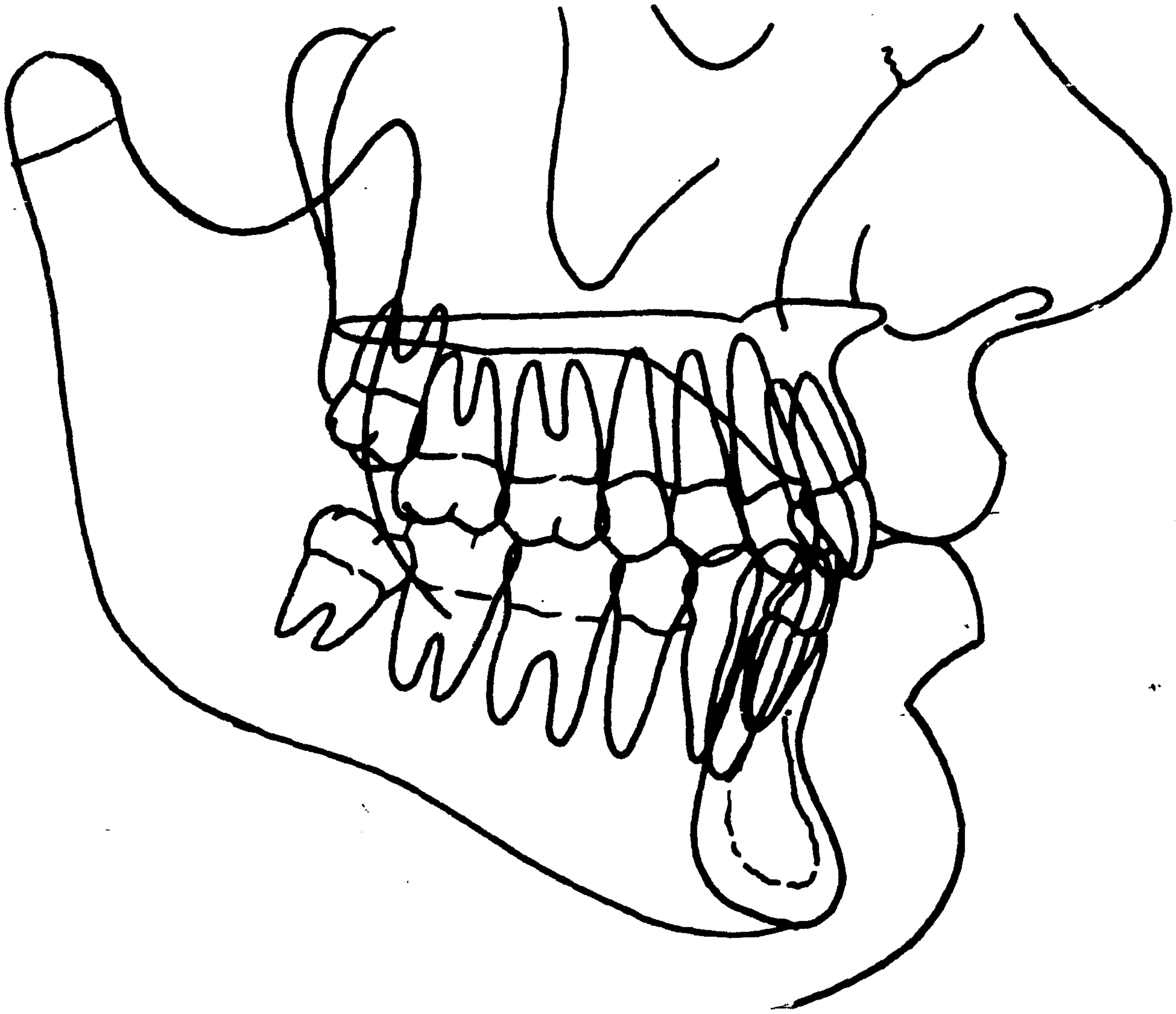


Fig. 1: !deal intercuspatian in buccal view
(Angle Class I occlusal relationship)

3.2.2 Incisor overjet

Measured in millimetres as the distance parallel to the occlusal plane from the incisal edges of the most labial maxillary central incisor to the corresponding most labial mandibular central incisor (OJB) (Fig. 2). The normal range was represented by a score of 0 while scores of 2, 3 and 4 represented overjets of 3,5 - 6,0mm, 6,5 - 9,0mm and 9,0mm or more respectively.

3.2.3 Incisor overbite

Measured in millimetres as the deepest vertical overlap of the maxillary and mandibular central incisors (OBB) (Fig. 3). The ideal range was considered to be 0,0 - 3,0 mm and given a score of 0. Scores of 2 and 3 represented overbites of 3,5 - 5,0mm and 5,5mm or more respectively.

3.2.4 Anterior openbite

Measured in millimeters as the amount of space in the vertical plane between lower and upper incisors or palatal mucosa, with the study models in centric occlusion, but without the bite wax (Fig. 4). The ideal for this parameter was considered to be 0,0mm which was represented by a score of 0. If an overbite existed with an openbite present a score of 1 was given. Openbites of 0,0 - 3,0mm and 3,0mm or more, were given scores of 2 and 3 respectively.

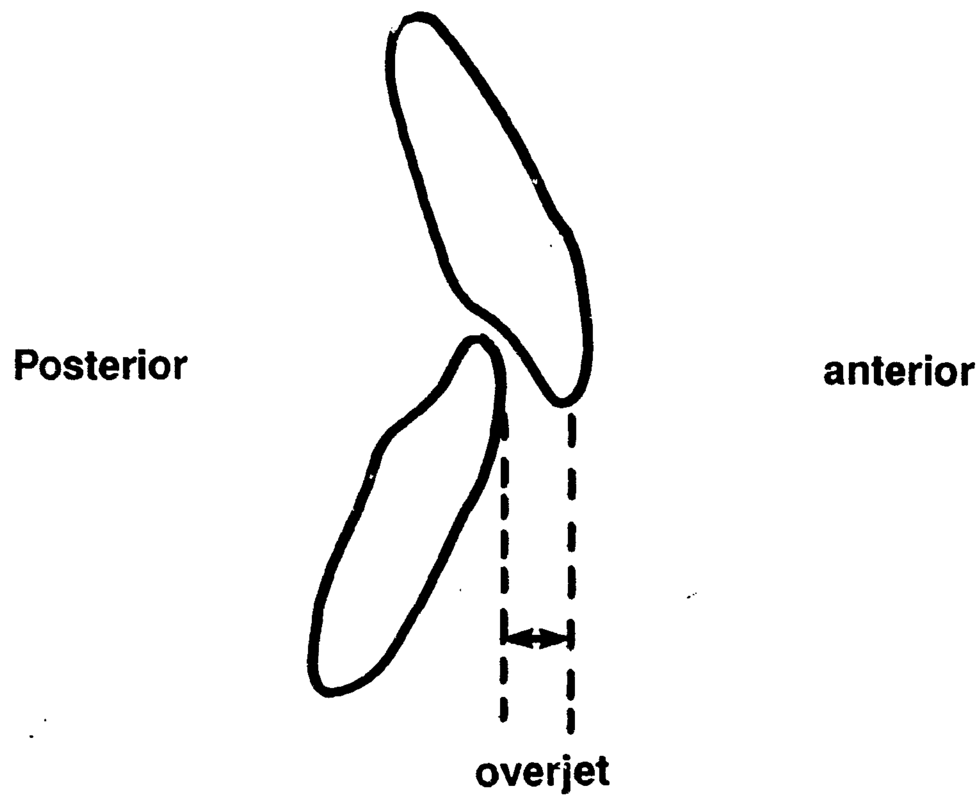


Fig. 2: Overjet in sagittal view

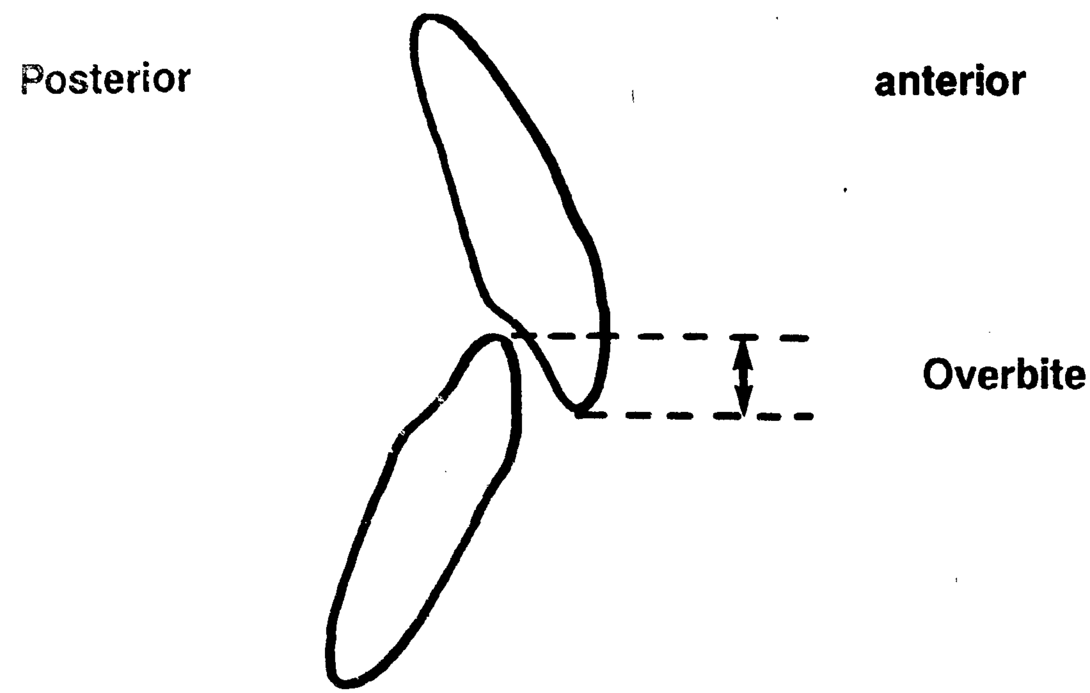


Fig. 3: Overbite in sagittal view

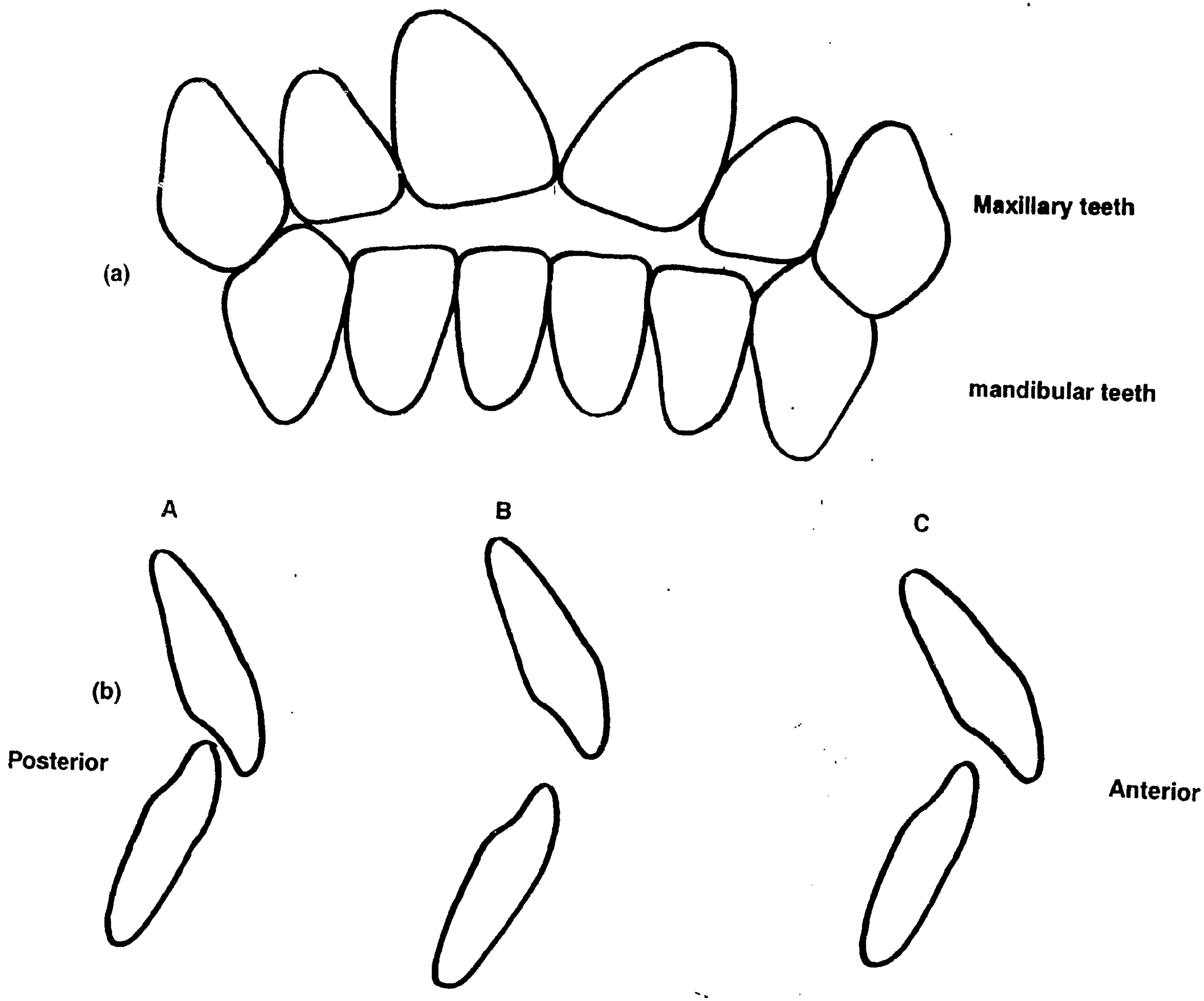


Fig. 4: Anterior openbite (a) Anterior view (b) Sagittal view
A - Normal incisor relationship
B - Openbite without incisor overbite
C - Openbite with incisor overbite

3.2.5 Anterior crossbite

Recorded according to a system which recognises three sub-categories (Sadowsky and Sakols, 1982):

i) none (score 0)

ii) 1-2 teeth (score 1)

iii) 3-4 teeth (score 2)

No teeth in crossbite was regarded as ideal (Fig. 5).

3.2.6 Posterior crossbite

Recorded by a system which recognises this feature as being (Sadowsky and Sakols, 1982):

i) absent (score 0)

ii) unilateral (score 1)

iii) bilateral (score 2)

No consideration was given to the actual number of teeth involved or the presence of a functional shift. Absence of crossbite was regarded as ideal (Fig. 6).

3.2.7 Maxillary and mandibular crowding

Measured in millimetres as the difference between the space available in the dental arch to accommodate the secondary teeth (from first molar to first molar) and the sum of the mesiodistal widths of the secondary teeth (from first molar

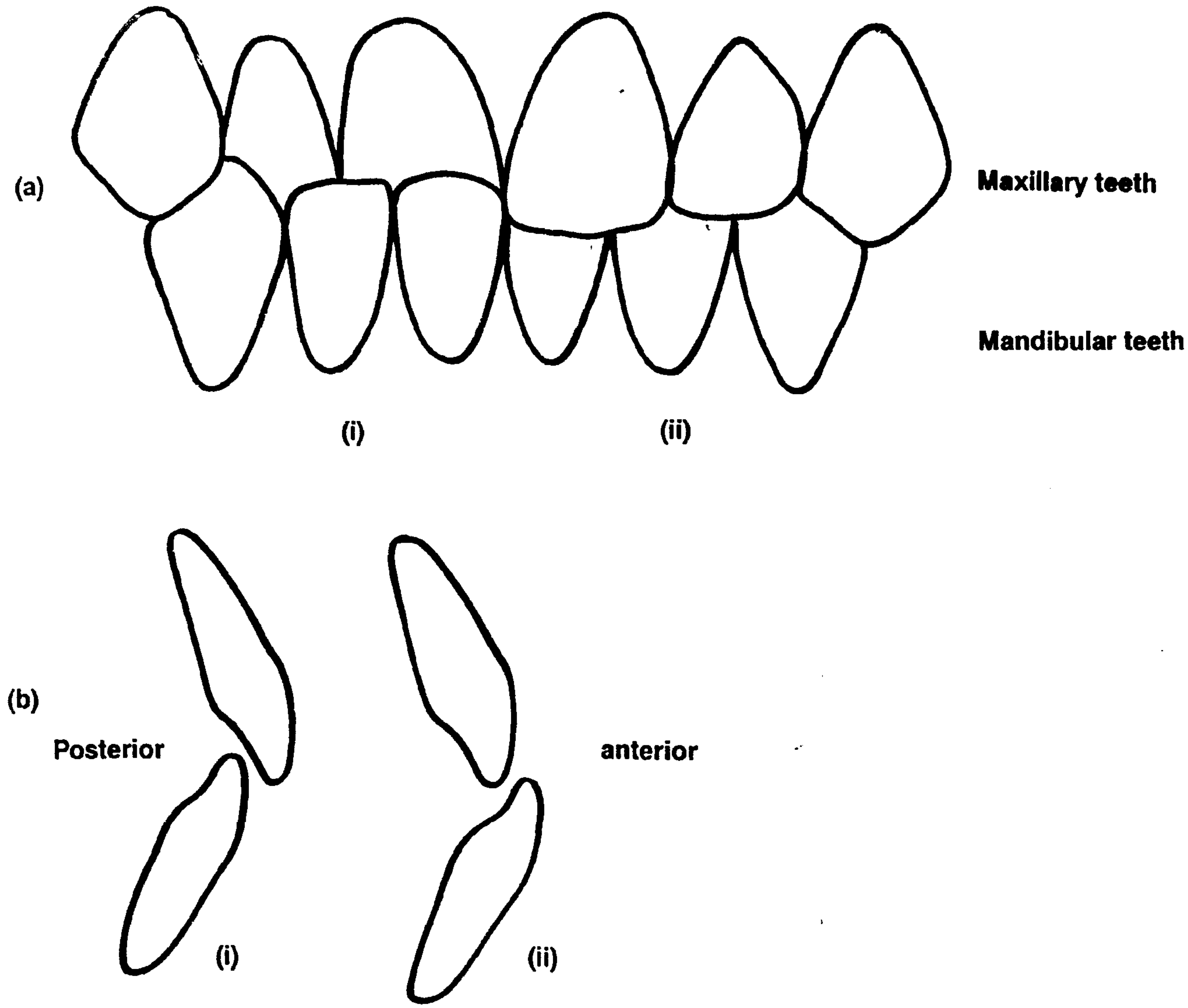


Fig. 5: Anterior crossbite
(a) Anterior view
(i) Anterior crossbite (ii) Normal overbite
(b) Sagittal view
(i) Normal overbite/overjet (ii) Crossbite (reversed or negative overbite/overjet)

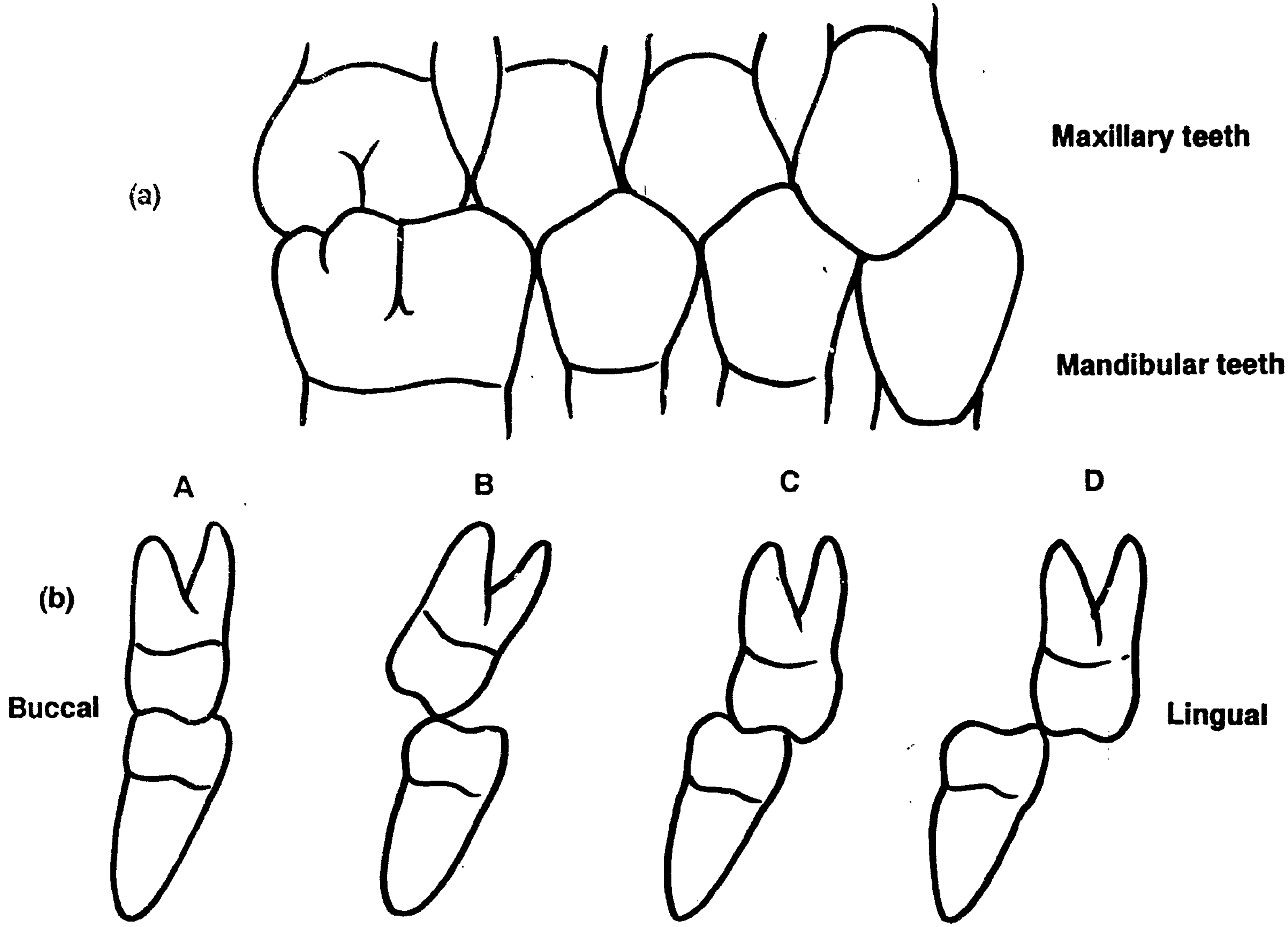


Fig. 6: Posterior crossbite
(a) Sagittal view with canine in normal relationship and premolars and molar in crossbite
(b) Transverse view of molars
A - Normal bucco-lingual relationships
B - Buccal crossbite
C - Lingual crossbite
D - Complete lingual crossbite (scissorsbite)

to the opposite first molar). The method described by Moyers (1988) was used to establish the crowding (Fig. 7). The millimetre difference between the arch length and the sum of the tooth measurements was given a score value which represented the degree of crowding present. The ideal range was considered to be 0,0 - 3,0mm and this was regarded as the norm. Most of the crowding occurred in the lower anterior segment of the dental arch and therefore the amount of anterior irregularity was also measured according to the method described by Little (1975). Little expressed this measurement as the Little Irregularity Index (Fig. 8).

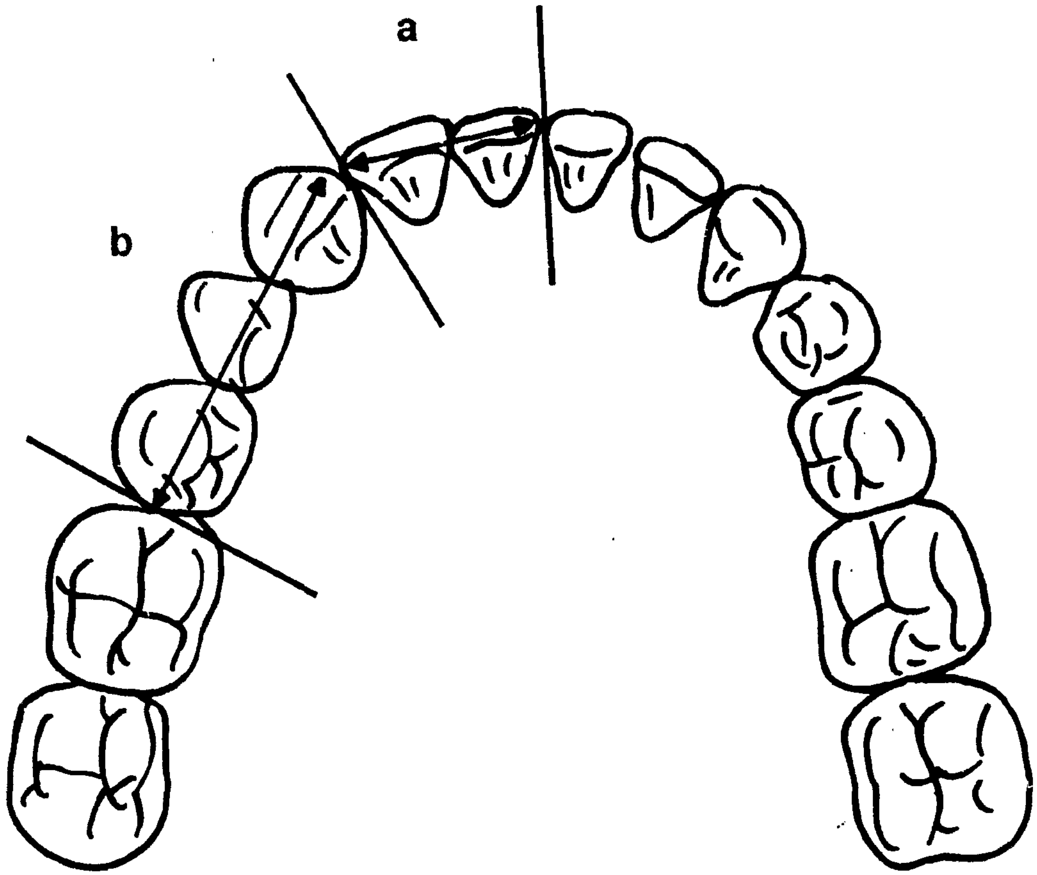
The crowding was represented by certain score values:

i) 0,0 - 3,0mm (score 0)
ii) 3,5 - 6,0mm (score 1)
iii) 6,5mm or more (score 2)

3.2.8 Mandibular intercanine width

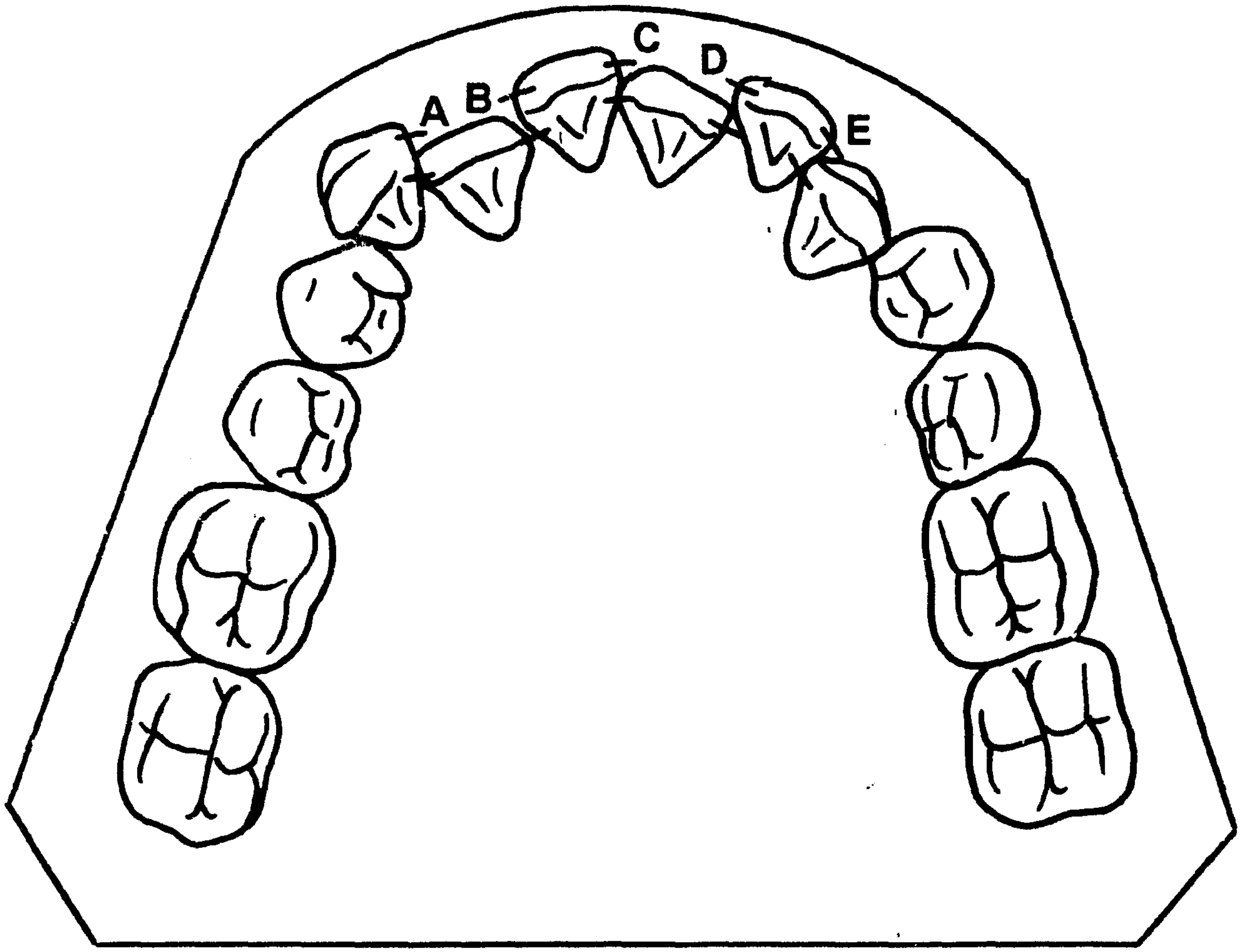
Two different measurements were recorded and the values scored as actual millimetre measurements (Fig 9):

a) the distance measured in millimetres at the gingival margins on the mid-axis of the labial surfaces of the canines (L3-3B) (Seedat, 1984).
b) the distance between cusp tips or estimated cusp tips in the cases of wear facets (L3-3I) (Walter, 1962; Little and Riedel, 1989).



a = mm b = mm
(a + b) – (Mesiodistal dimentions of teeth in a + b)
= space shortage for one quadrant

Fig. 7: Assessment of crowding/space shortage



A + B + C + D + E = IRREGULARITY INDEX

Fig. 8: Little Irregularity Index (Angle Orthodontist 60:257, 1990)

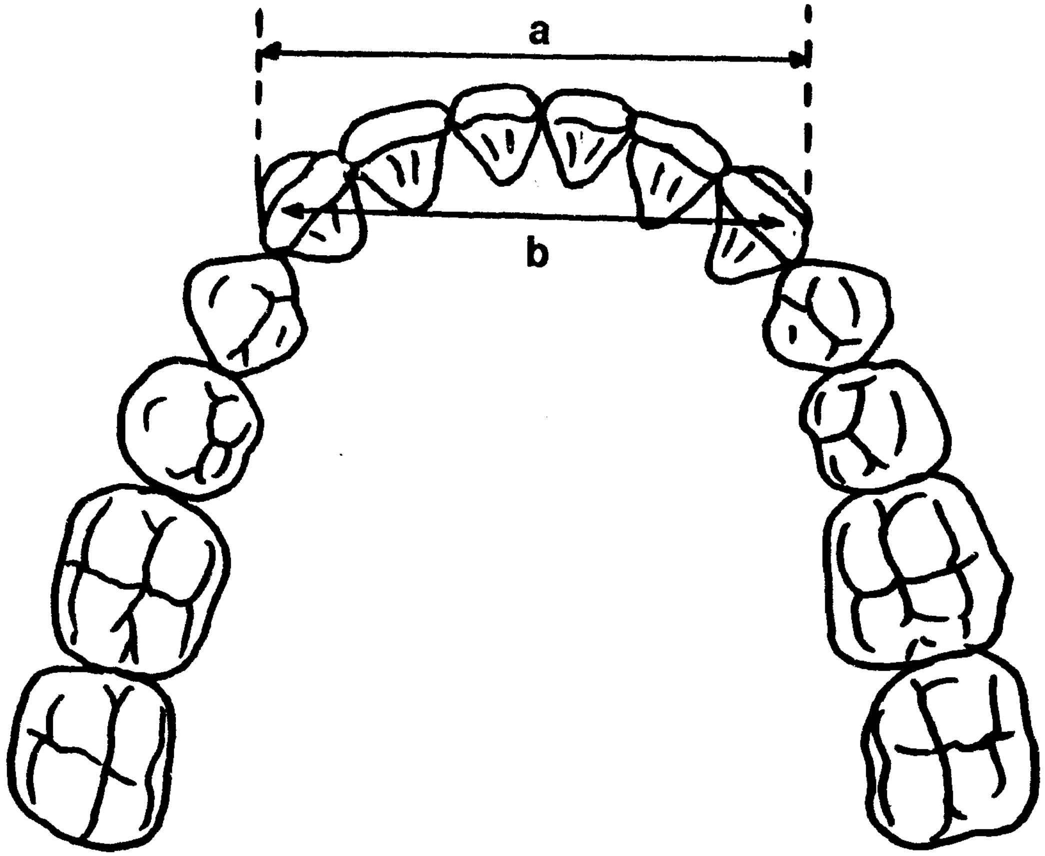


Fig. 9: Mandibular intercanine width
(a) Buccal measurment
(b) Intercuspal measurement

3.2.9 Maxillary intermolar width

Two different measurements were recorded and the values scored as actual millimetre measurements (Fig. 10):

a) the distance measured at the gingival margins of the mesiobuccal cusps of the first molars present (U6-6B) (Seedat,1984).

b) the distance measured at the cusp tips of the mesiobuccal cusps or estimated cusp tips in cases of wear facets (U6-6I). Similar measurements were made of mandibular bimolar widths (Walter, 1962).

3.2.10 Rotations

Rotation of a tooth or teeth were recorded as the deviation from a line through the central mid-fossae area (Fig. 11). The ideal range was taken to be 0 - 15 degrees and this norm was represented by a score of 0 (Fig. 11). A score of 1, 2, and 3 correlated with rotations between 15,5 - 90 degrees, 90,5 - 135 degrees and 135,5 - 180 degrees respectively.

3.2.11 Curve of Spee

Measured in millimetres as the perpendicular distance between a line connecting the distal cusp of the most posterior molar and the interproximal contact of the mandibular central incicors and the deepest point of the premolar area (Fig. 12). The ideal range was 0,0 - 1,5mm

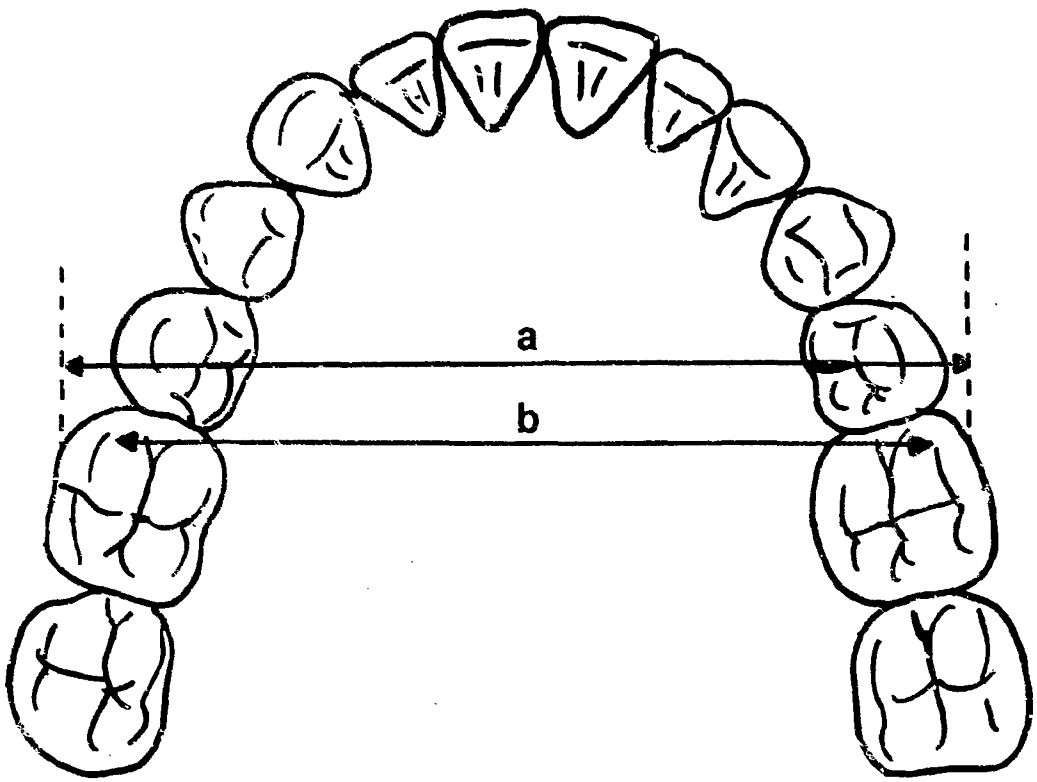


Fig. 10: Maxillary intermolar width
(a) Buccal measurement (b) Intercuspal measurement

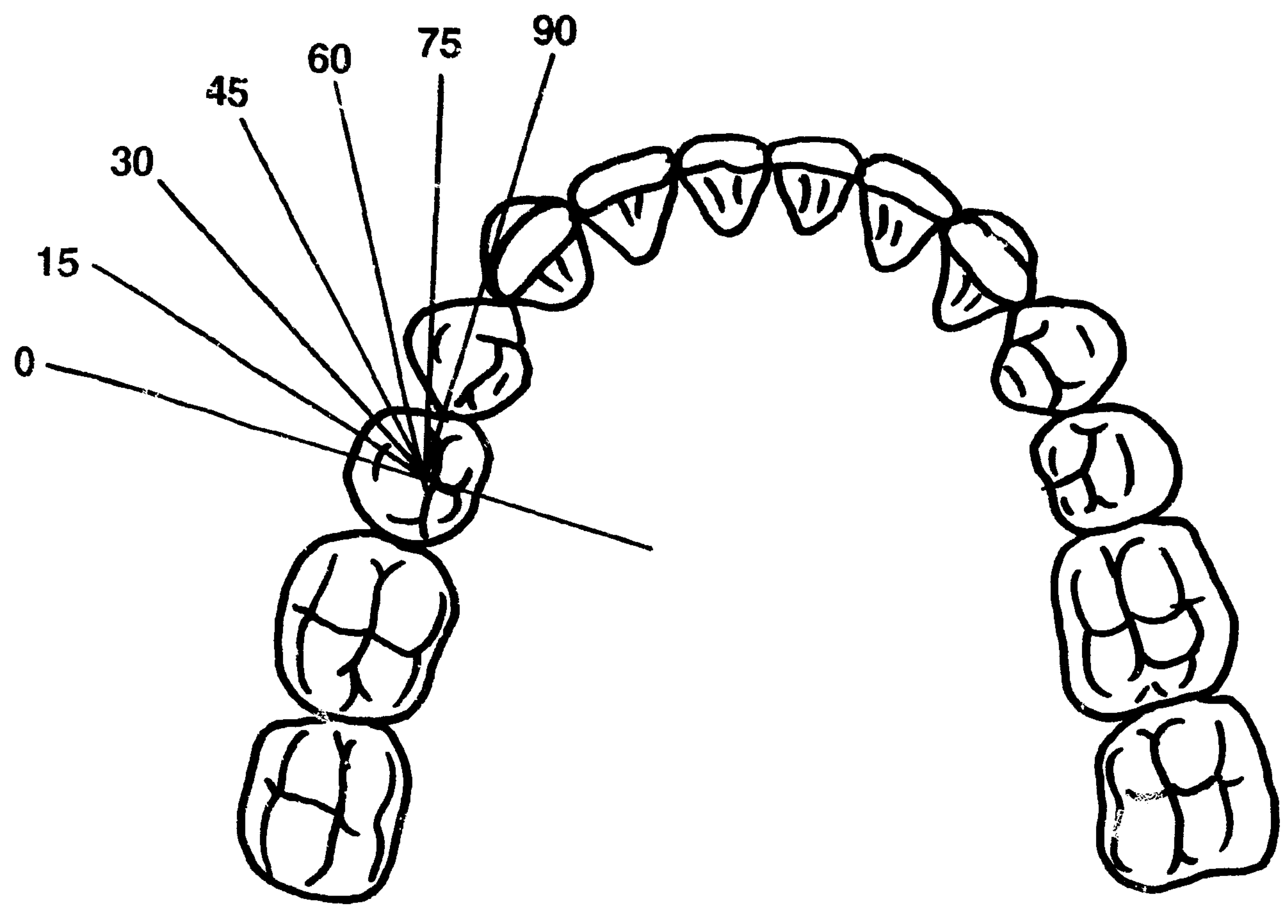


Fig. 11: Mensuration of rotation; Deviation from mid-fossa occlusal line (degrees)

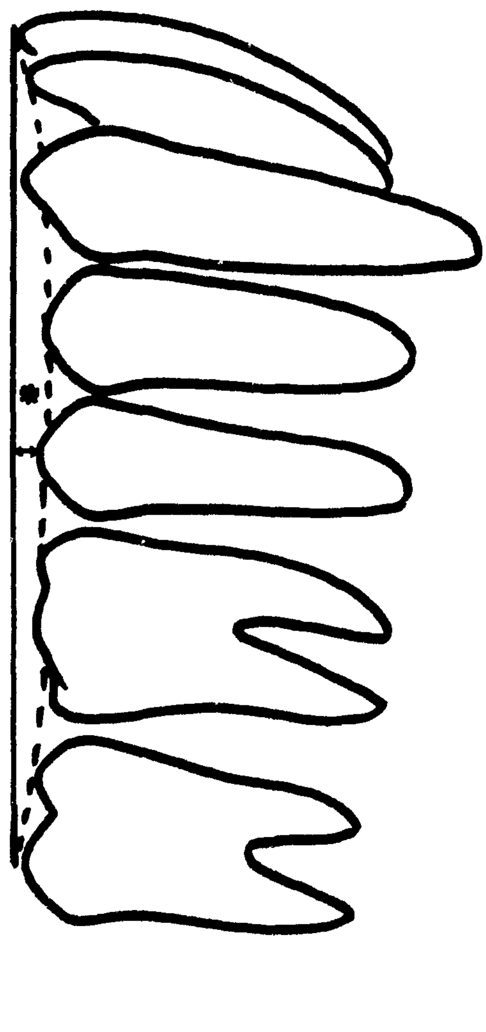


Fig 12: Mandibular arch; Curve of spee
* Normal measurement 1,5mm

which was represented by a score of 0. Scores of 1 and 2 were given to curves of Spee between 2,0 - 4,0mm and 4,5mm or more respectively.

3.2.12 Total malocclusion score

The total malocclusion score was assessed according to a method which was similar to that advocated by Sadowsky and Sakols (1982). It was recorded as an additional metrical character to determine whether an orthodontic correction of a dentition had remained stable. The total score was an aggregate of the scores of:

i) the molar and canine relationship
ii) anterior openbite
iii) anterior and posterior crossbite
iv) overjet and overbite
v) maxillary and mandibular crowding
vi) rotations
vii) curve of Spee

as well as the actual numerical measurements of:

i) lower intercanine buccal measurement
ii) upper intermolar buccal measurement

3.2.13 Bolton tooth-size discrepancy

The Bolton tooth-size ratio analysis gives an indication of the degree of interarch discrepancy in the total as well as the anterior mandibular versus maxillary tooth-size ratios.

These ratios help to estimate the overbite and overjet relationships which will likely be obtained after treatment is completed, the effects of contemplated extractions on the posterior occlusion and incisor relationships, and the degree of occlusal misfit produced by interarch tooth-size incompatibilities. A total mean ratio of 91,3% and anterior mean ratio of 77,2% were described as the acceptable norms (Bolton, 1958, 1962).

3.2.14 Arch length

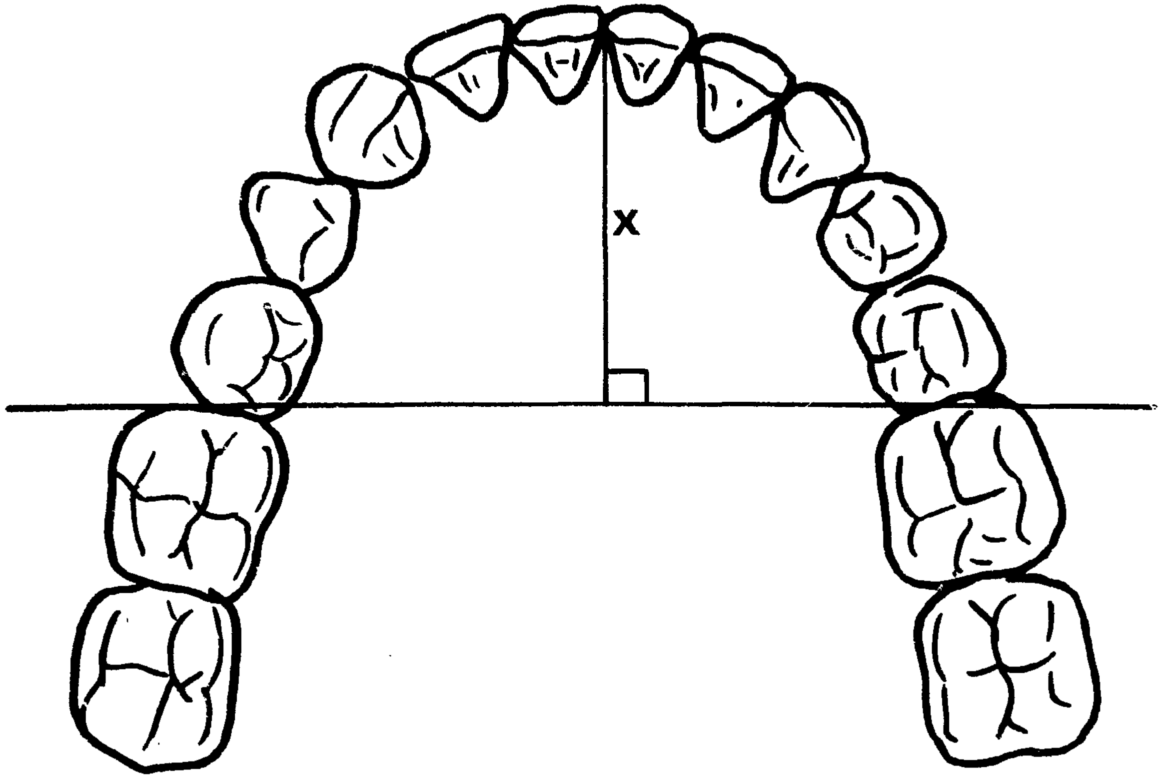
Two different methods were used to measure this parameter:

a) the distance measured in millimetres between the most anterior mandibular incisor and the line connecting the mesial of the mandibular first molars (ARCHL) (Gardner and Chaconas, 1976) (Fig. 13).

b) the sum of the right and left distances from mesial anatomic contact points of the permanent molars to the contact point of the central incisors or, if spaced, to the midpoint between the central incisor contacts (LITTLE-A) (Little and Riedel, 1989; Little, Riedel and Engst, 1990) (Fig. 14).

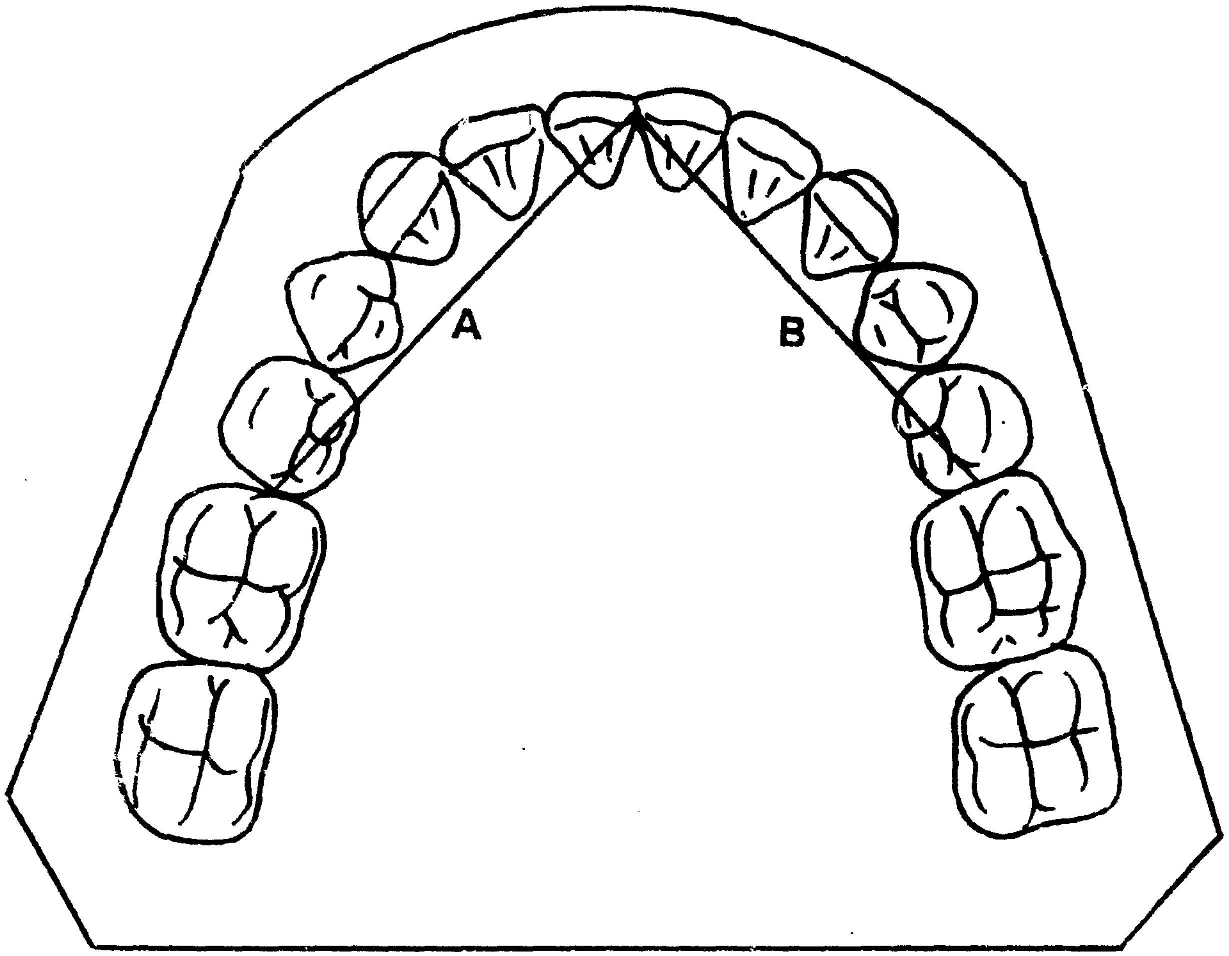
3.2.15 Extraction

Teeth which were extracted as part of the orthodontic treatment were recorded. It was also noted when nonextraction treatment was performed. Any extraction spaces remaining after active treatment, or recorded in the



X = Arch length

Fig. 13: Conventional arch length



A + B = Arch length

Fig. 14: Little arch length (Angle Orthodontist 60:257, 1990)

post-retention phase, were monitored in order to assess whether these spaces close according to the philosophy of anterior drifting of teeth (Moyers, 1988).

3.2.16 Teeth present

All teeth present during the various phases were recorded.

3.2.17 Classification

The dentition was classified according to the position of the first molars. This system of classification was described by Angle (1899, 1907). Modifications were later added by Dewey (1942).

All occlusions were thus divided into one of three classes:

a) Angle Class I:

The normal mesiodistal (antero-posterior) relation of the dental arches, represented by the mesiobuccal cusp of the maxillary first permanent molar fitting in the buccal grove of the mandibular first permanent molar (Lischer, 1928 - Neutroclusion).

Dewey modifications to Class I:

Type I - crowded incisors; the canines frequently labial.

Type II - protrusion of the maxillary incisors.

Type III - one or more of the maxillary incisors in linguoversion to the mandibular incisors (anterior cross-bite).

Type IV - molars alone or molars and premolars in buccal or linguoversion to the mandibular teeth (posterior cross-bite).

Type V - mesial drifting of molars resulting from premature loss of teeth.

b) Angle Class II:

The mandibular arch is distal to normal in its relation to the maxillary arch as characterized by the position of the mesiobuccal cusp of the maxillary first permanent molar fitting into the buccal embrasure between the mandibular first permanent molar and second premolar (Lischer, 1928 - Distoclusion).

i) division 1 - bilaterally distal with protruding maxillary incisors.

ii) division 2 - bilaterally distal with retruding maxillary incisors.

The addition to the abovementioned two divisions, the term subdivision, indicates a unilateral malocclusion.

c) Angle Class III:

This category is characterized by the mesial relation of the mandibular arch to the maxillary arch and it may be identified by the position of the mesiobuccal cusp of the maxillary first permanent molar fitting into the buccal embrasure between the first and second mandibular permanent molars (Lischer, 1928 - Mesioclusion). Dewey also added modifications to the Class III occlusion to further describe this classification.

Dewey modifications to Class III:

Type I - maxillary and mandibular teeth in good alignment with the incisors in an edge-to-edge bite.

Type II - maxillary teeth in good alignment; mandibular incisors lingual to maxillary incisors but definitely crowded.
Type III - maxillary teeth at times crowded; mandibular teeth in good alignment; but the mandibular incisors are labial to the maxillary incisors.

As noted previously, each classification was also compared to a cephalometric skeletal classification utilising amongst others the ANB angle (Steiner, 1953, 1959, 1960) and the WITS appraisal (Jacobson, 1975, 1976).

3.2.18 Little Irregularity Index

This index was measured in millimetres according to the method described by Little (1975). It gives an indication of anterior crowding (L-IRREG) (Fig. 8).

The scoring method involved measuring the linear displacement of the anatomic contact points (as distinguished from the clinical contact points) of each mandibular incisor from the adjacent tooth anatomic contact point, the sum of these five displacements representing the relative degree of anterior irregularity. Perfect alignment from the mesial aspect of the left canine to the mesial aspect of the right canine was given a score of 0, with increasing crowding represented by greater displacement and, therefore, a higher index score. The following scores were allocated as described by Little:

0	Perfect alignment
1-3	Minimal irregularity
4-6	Moderate irregularity
7-9	Severe irregularity
10	Very severe irregularity

The Little Irregularity Index represents the distance that the anatomic contact points had to be moved to gain ideal anterior alignment (Little, 1975). Each of the five measurements was obtained directly from the mandibular study cast rather than intraorally, since proper positioning of the caliper is essential for consistent accuracy. The caliper was held parallel to the occlusal plane while the beaks were lined up with the contact points to be measured. Each of the five measurements represented a horizontal linear distance between the vertical projection of the anatomic contact points of adjacent teeth. Contact points of anterior teeth can vary in the vertical plane, but correction of vertical displacement will not appreciably affect anterior arch length; therefore, all vertical discrepancies of contact points may be disregarded (Little,1975). By holding the caliper consistently parallel to the occlusal plane the evaluator ensured each measurement was reflected only in a horizontal displacement.

3.3 Cephalometric measurements

The cephalometric measurements were performed by digitizing various landmarks on a cephalogram utilising a digitizer (Hipad DT-II digitizer, Houston Instuments, Austin, Texas.

U.S.A.) connected to an IBM compatible microcomputer (Multitech Mac-PC I, Multitech Industrial Corp., Rep. of Taiwan) and using the OLI Cephalometric Software Package (Orthodontic Logic, Incorporated, P.O.Box 22473, Kansas City, Missouri 64113, U.S.A.) incorporating the following analyses:

i) Basic cephalometric analysis.
ii) Ricketts analysis.
iii) Björk/Jarabak analysis.
iv) Holdaway soft tissue analysis.
v) Wits appraisal.
vi) Analysis of upper incisor to Facial axis, A-Pogonion and to Frankfurt horizontal.

Plotted examples of the abovementioned analyses are portrayed in Figures 15, 16, 17 and 18.

3.3.1 Definitions of radiographic landmarks used as seen on a lateral cephalometric radiograph

The landmarks are portrayed in Figure 19.

1. IX1 Index point 1:

The first of three index points used to relate the plotter drawing to the x-ray film. Located outside the anatomical perimeter in front of soft tissue nasion. Selected arbitrarily (Oliceph, 1983).

BASIC CEPHALOMETRIC ANALYSIS

Patient WILSEN, KATHY # 1
Status PRE-TREATMENT
Age/Sex 12. 3 Female
X-Ray 06/24/88
ID 84-3228-7
Doctor DEPT.OF ORTHODONTICS

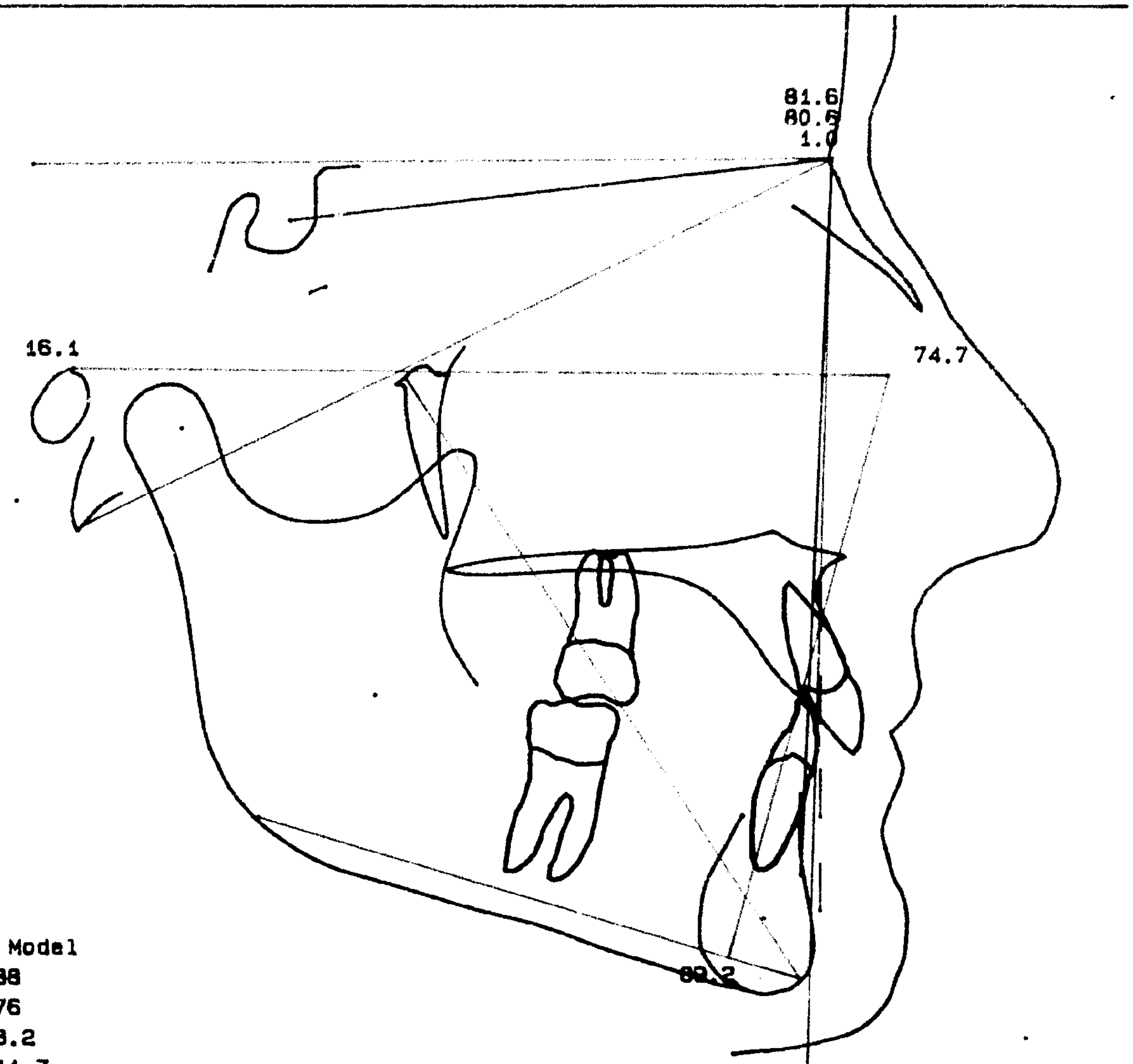


FIG 15

Acceptable IMPA Window is 85 to 95 deg
Prerotation Incisor Intrusion is 0 mm
Incisor Rotation Center is 15 mm From Tip

	Ideal	Patient	Non-Extract	Model
IMPA	85-95	89.2	88	88
FMIA	65-68	74.7	76	76
/1 to APo	-1 to 3	-2.9	-3.2	-3.2
/1 to NB	25	13	11.7	11.7
/1 to NB (mm)	4	-1.2	-1.5	-1.5

Arch Length Discrepancy =Within Limits

Scale: 107.5%

RICKETTS ANALYSIS

Patient WILSEN, KATHY # 1
Status PRE-TREATMENT
Age/Sex 12. 3 Female
X-Ray 06/24/88
ID 84-3228-7
Doctor DEPT.OF ORTHODONTICS

NORMS

Go'Gn' to FH	22-30 deg.
NPo to FH	84-90 deg.
PtGn' to NBa	87-93 deg.
N-Gn'-Go'	65-71 deg.
PM-Xi-DC	22-30 deg.
ANS-Xi-PM	43-51 deg.
A to NPo	0 to 4 mm.
/1 to APo	18-26 deg.
/1 to APo	-1 to 3 mm.
6/ to PTV	14 to 19 mm.
/M LIP to E	-4 to 0 mm.

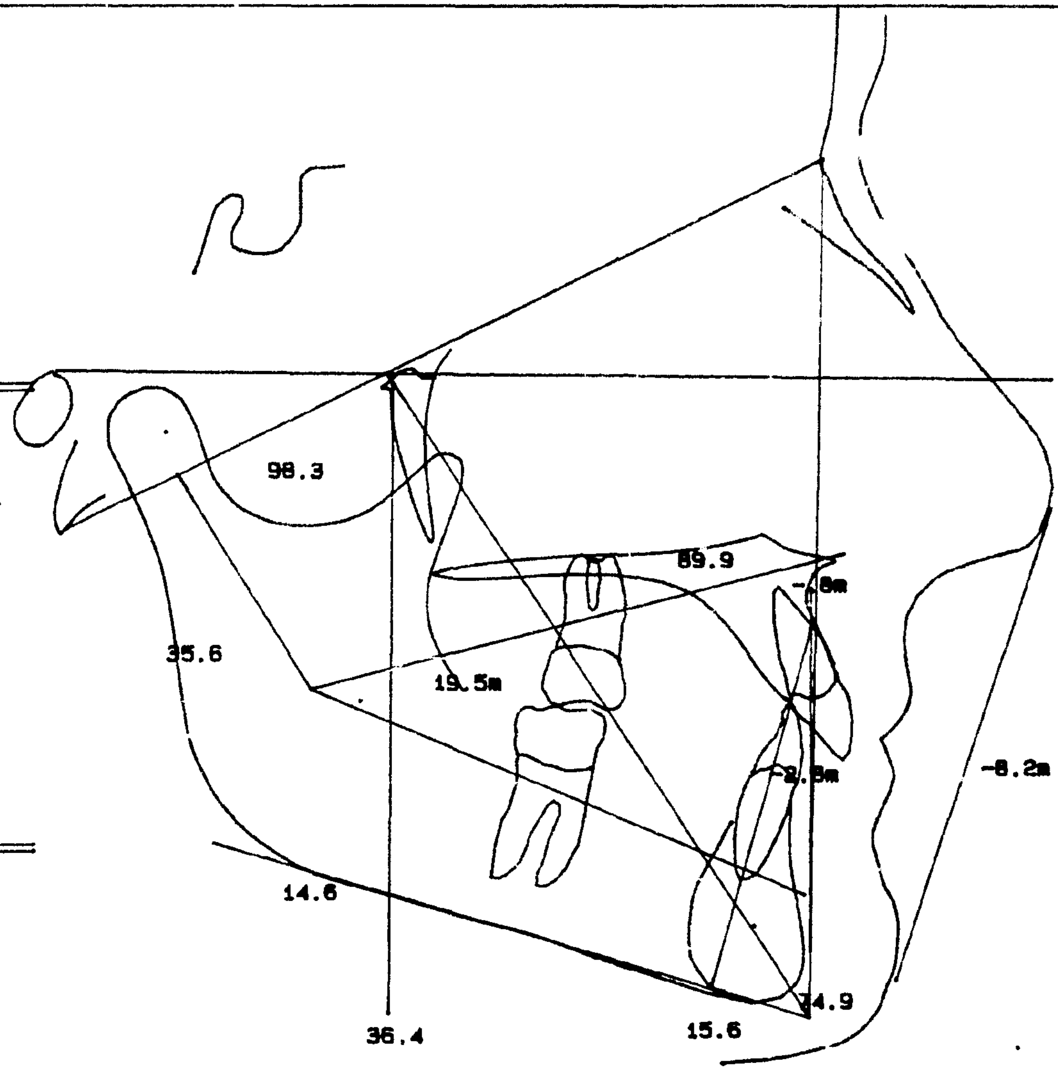


FIG 16

Scale: 107.5%

(C) 1988 by Orthodontic Logic, Inc. 1.00 PC Type/7475A UNIVERSITY OF STELLENBOSCH 00211248 01:23 01-01-1980

BJORK/JARABAK ANALYSIS

Patient WILSEN, KATHY # 1
Status PRE-TREATMENT
Age/Sex 12. 3 Female
X-Ray 06/24/88
ID 84-3228-7
Doctor DEPT.OF ORTHODONTICS

NORMS

NSAr	118-128 deg.
SArGo'	137-149 deg.
ArGo'Me	123-137 deg.
SN	68 to 74 mm.
SAr	29 to 35 mm.
ArGo'N	52-55 deg.
NGo'Me	70-75 deg.
ArGo'	39 to 49 mm.
Go'Me	66 to 76 mm.
SGo'	70 to 85 mm.
NMe	105 to 120 mm.
SGo'/NMe	63 to 68 %.
Go'Me/SN	1.
SNPo	77-80 deg.
Post-Ant FH	60 to 64 %.

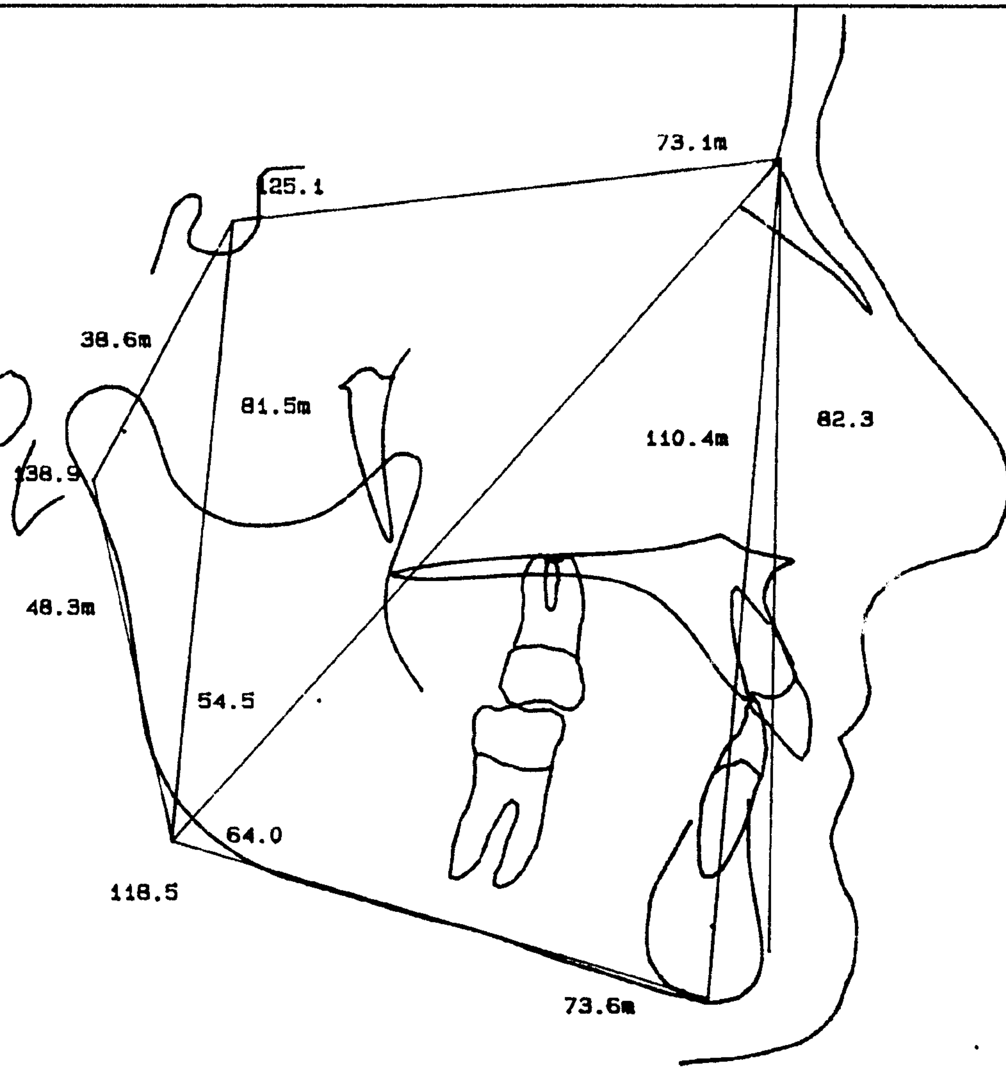


FIG 17

Scale: 107.5%

HOLDAWAY AND MORE

Status PRE-TREATMENT
Age/Sex 12. 3 Female
X-Ray 06/24/88
ID 84-3228-7
Doctor DEPT.OF ORTHODONTICS

USER GROUP A

Variable	Value
Soft Tissue Facial	92.3 deg.
Nose Prominence (mm)	19.3 mm.
Superior Sulcus Depth	-3.7 mm.
Soft A to H Line (mm)	1.3 mm.
A Point Convexity	-.5 mm.
Upper Lip Thickness	13.6 mm.
Upper Lip Taper	8.3 mm.
Upper Lip Strain	5.3
H-Angle	5.8 deg.
Lower Lip to H-Line	-1.4 mm.
Inf. Sulcus to H-Line	3.6 mm.
Soft Tissue Chin (mm)	12 mm.
WITS Analysis	-1.8 mm.
1/ to Frankfort Horiz	112.6 deg.
1/ to Facial Axis	11.4 deg.
1/ to APo (mm)	4.3 mm.

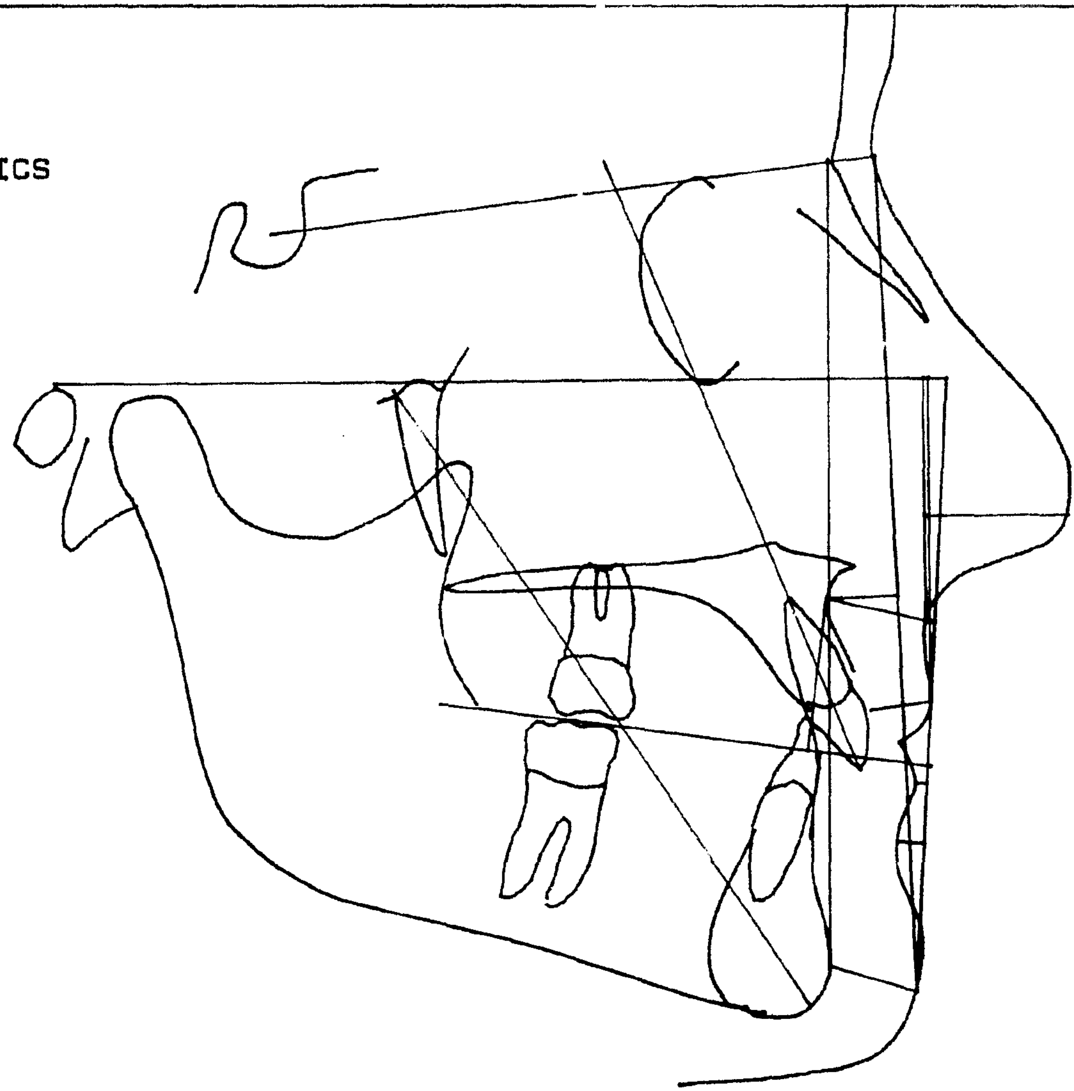
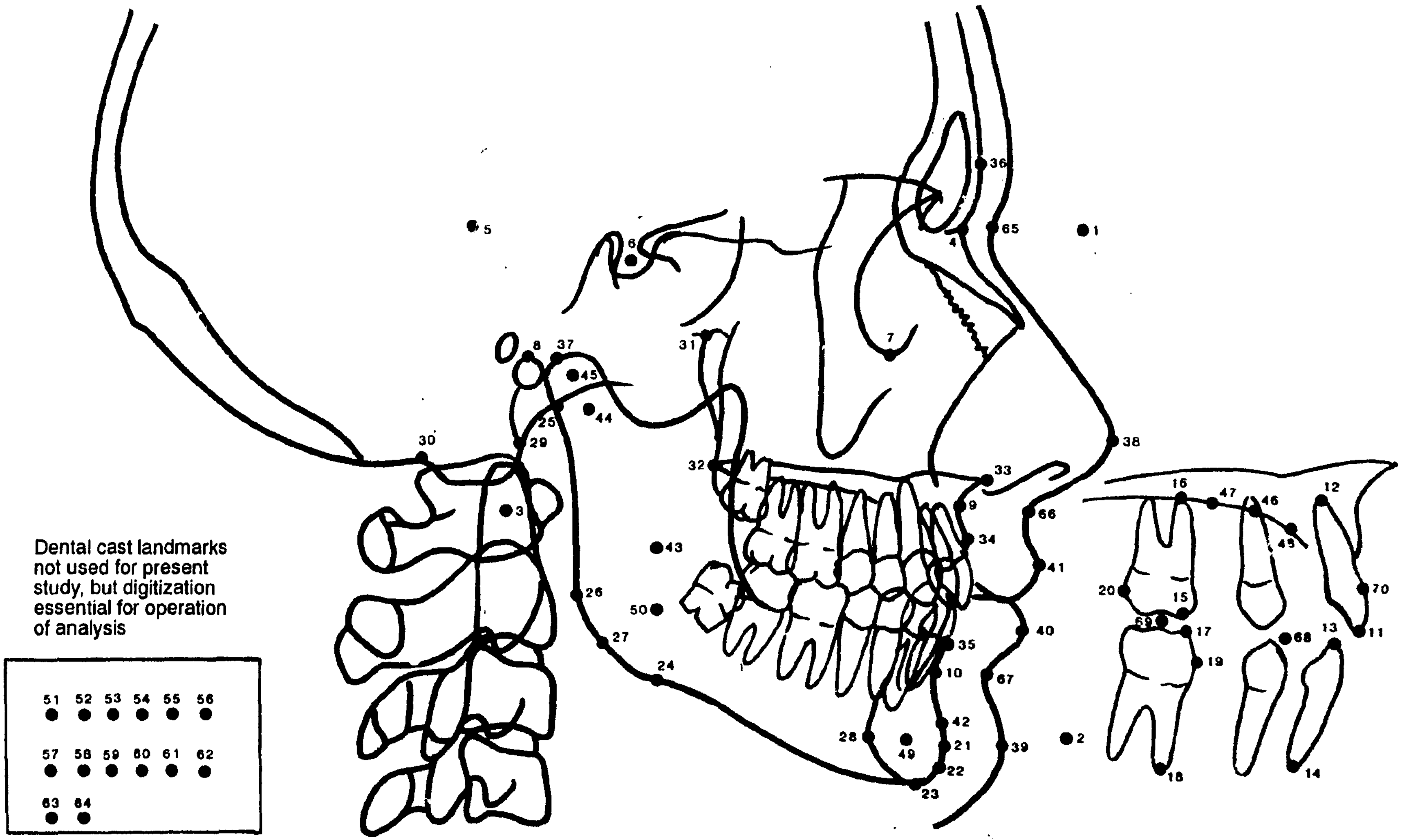


FIG 18

Scale: 107.5%

Fig.19: Landmark locations necessary for use of Oliceph Cephalometric Analysis



2. IX2 Index point 2:

The second of three index points used to relate the plotter drawing to the x-ray film. Located outside the anatomical perimeter in front of soft tissue chin. Selected arbitrarily (Oliceph, 1983).

3. IX3 Index point 3:

The third of three index points used to relate the plotter drawing to the x-ray film. Located near the geometrical centre of the odontoid process of the axis (second cervical vertebra). Selected arbitrarily (Oliceph, 1983).

4. N Nasion:

This midsaggital point marks the most anterior limit of the nasofrontal suture (Hrdlicka, 1920). It is also described as the junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose (Riolo et al., 1974, 1979).

5. Posterior Horizontal Point:

A point in the "true horizontal plane" passing through Nasion. Located posterior to Nasion at a distance equal to the length of the film image of the magnification scale (Oliceph, 1983).

6. S Sella:

The centre of the pituitary fossa of the sphenoid bone as seen in a cephalometric radiograph. Located by visual inspection (Riolo et al., 1974, 1979). It takes into consideration the antero-posterior, as well as the supero-inferior midpoint of the sella turcica (Preston, 1986).

7. Or Orbitale:

The lowest point on the average outline of the left and right bony orbits (Riolo et al., 1974, 1979). It is also described as the lowest point on the outline of the inferior or infraorbital margin of the left bony orbit (Preston, 1986).

8. Po Anatomic Porion:

The most superior point on the radiographic outline of the left external auditory meatus. If not discernible, the most superior point on the left ear rod of the cephalostat may be used (machine porion) (Oliceph, 1983).

9. A A Point:

This landmark is also referred to as point subnasale. It is the most posterior point on the bony outline of the maxilla (radiographic contour) between the Anterior Nasal Spine and Supradentale (Downs, 1948; Riolo et al., 1974, 1979). This point is assumed to lie in the mid-sagittal plane of the face (Preston, 1986).

10. B B Point:

The point furthest posterior from a line joining Infradentale and Pogonion on the anterior surface of the symphyseal outline of the mandible (radiographic contour) (Downs, 1948). This point should lie within the apical third of the incisor roots. When there is no curvature in this region and identification is not possible using the abovementioned method, preceding or succeeding films may be used to clarify the situation as erupting teeth obscure mandibular concavity on occasion (Riolo et al., 1974, 1979).

11-18. These landmarks are digitized using the OlI Template Position Landmarks (Oliceph, 1983):

11. Upper incisor incisal tip
12. Upper incisor root apex
13. Lower incisor incisal tip
14. Lower incisor root apex
15. Upper first molar mesial cusp tip
16. Upper first molar mesial root apex
17. Lower first molar mesial cusp tip
18. Lower first molar mesial root apex
19. Mesial tangent, lower first molar:

Located perpendicular to the occlusal plane. Average of left and right sides (Oliceph, 1983).

20. Distal tangent, upper first molar:

Located perpendicular to true horizontal plane. Average of left and right sides (Oliceph, 1983).

21. Pog Pogonion:

The most anterior point on the contour of the bony chin as seen on a lateral cephalometric radiograph. If this is an area rather than a specific point, pogonion is the point at which the anterior outline of the chin begins to curve posteriorly (i.e. the lowest point on the area of tangency determined by a tangent through Nasion) (Riolo et al., 1974, 1979; Oliceph, 1983). Pogonion is assumed to lie in the median plane (Preston, 1986).

22. Gn Gnathion:

The most anterior-inferior point on the contour of the bony chin symphysis as seen on a lateral cephalometric radiograph. Located by projecting onto the chin the bisector of the angle formed between the mandibular plane and the Nasion - Pogonion plane (Riolo et al., 1974, 1979).

23. Me Menton:

The most inferior point on the symphyseal outline of the chin as seen on a lateral cephalometric radiograph (Riolo et al., 1974, 1979). It is the point at which the mandibular plane is tangent to the symphysis (Oliceph, 1983). It is also described as the most caudal point in the median sagittal outline of the mandibular symphysis (Krogman and Sassouni, 1957) and corresponds to the craniological gnathion (Preston, 1986).

24. Posterior point on the mandibular plane:

An arbitrarily selected point on a line that passes through Menton and which is tangent to the average outline of the left and right posterior-inferior border of the mandible (Oliceph, 1983).

25. Ar Articulare (Articulare posterior):

The intersection of the average outline of the posterior borders of the left and right condylar necks as seen on a lateral cephalometric radiograph and the image of the inferior border of the occipital bone (Inferior cranial base) (Björk, 1947; Riolo et al., 1974, 1979; Oliceph, 1983).

26. Inferior point on the posterior border line:

An arbitrarily selected point on a line that passes through Articulare above and is tangent to the average cephalometric outline of the posterior borders of the left and right rami below (Oliceph, 1983).

27. Go Gonion:

The midpoint of the angle of the mandible. Located by projecting onto the radiographic outline of the mandible the bisector of the angle between the mandibular plane and the Articulare - Inferior tangent ramus point (Riolo et al., 1974, 1979; Oliceph, 1983).

28. Lingual symphyseal point:

The point at which the lingual surface of the symphysis as seen on a lateral cephalometric radiograph is intersected posteriorly by a line passing through Pogonion parallel to the mandibular plane (Oliceph, 1983).

29. Ba Basion:

The most inferior and posterior midline point on the anterior margin of the foramen magnum as seen on a lateral cephalometric radiograph (Riolo et al., 1974, 1979). It is alao referred to as the external basion or ectobasion (Preston, 1986).

30. Bo Bolton point:

The highest point of the average of the left and right postcondylar notches of the occipital bone (Broadbent, Broadbent and Golden, 1975; Oliceph, 1983).

31. Pt Point:

The inferior and posterior crest of the foramen rotundum. Average of left and right images (Ricketts et al., 1979).

32. PNS Posterior nasal spine:

The posterior limit of the hard palate as seen on a lateral cephalometric radiograph. This point is assumed to lie in the midline (Riolo et al., 1974, 1979; Oliceph, 1983).

33. ANS Anterior nasal spine:

The tip of the median, sharp bony process at the anterior limit of the maxilla. It is assumed to lie in the midline at the lower margin of the anterior nasal opening (Riolo et al., 1974, 1979). It corresponds to the craniological acanthion (Rakosi, 1982).

34. Sd Supradentale:

The labial alveolar crest of the upper central incisor (Oliceph, 1983) or the most anterior inferior point on the maxilla at its labial contact with the maxillary central incisor (Riolo et al., 1974, 1979).

35. Id Infradentale:

The labial alveolar crest of the lower central incisor (Oliceph, 1983) or the anterior superior point on the mandible at its labial contact with the mandibular central incisor (Riolo et al., 1974, 1979).

36. Gb Glabella:

The most anterior point on the outline of the frontal bone overlying the frontal sinus as seen on a lateral cephalometric radiograph at the level of the supra-orbital rim. Where this point is not readily apparent, the overlying soft tissue is used to locate it (Riolo et al., 1974, 1979; Oliceph, 1983).

37. Co Condylion:

The most posterior-superior point on the average outline of the left and right condylar heads. Located by projecting onto the condyle the bisector of the angle formed between a line parallel to the true horizontal plane that is tangent to the superior curvature of the condyle and a line that is tangent to the posterior curvature of the condyle above and tangent to the posterior outline of the ramus below. The Co point is, therefore, located as the most superior-posterior axial point of the condylar head rather than as the most superior point on the condyle (Riolo _et al_., 1974, 1979).

38. Nose tangent point (of E-Line):

The nose point of a soft tissue line that is tangent to the nose above and the chin below (Ricketts _et al_., 1979; Oliceph, 1983).

39. Chin tangent point (of E-Line):

The chin point of a soft tissue line that is tangent to the nose above and chin below (Ricketts _et al_., 1979; Oliceph, 1983).

40. Closest point on lower lip to E-Line:

Measured perpendicularly to the soft tissue nose-chin tangent line (Ricketts _et al_., 1979; Oliceph, 1983).

41. Closest point on upper lip to E-Line:

Measured perpendicularly to the soft tissue nose-chin tangent line (Oliceph, 1983).

42. Pm Protruberance menti:

The point on the anterior outline of the symphysis as seen on a lateral cephalometric radiograph between B Point and Pogonion where the curvature changes from concave to convex. If not discernable, use midpoint of the outline of the symphysis between B Point and Pogonion (Ricketts _et al_., 1979).

43. Point Xi:

The geometric centre of the left ramus. It is derived by locating the centre of a rectangle, the top side of which is parallel to Frankfurt horizontal and tangent to the deepest point of the sigmoid notch, the two vertical sides of which are tangent to the narrowest dimension of the anterior and posterior contours of the ramus and the bottom side of which intersects the inferior (external) contour of the mandible directly below the point at which the top side of the rectangle is tangent to the sigmoid notch (Ricketts et al., 1979).

44. Point DC:

The midpoint of that portion of the Nasion-Basion line that crosses the neck of the condyle (Ricketts et al., 1979).

45. Point VCC:

Visualized centre of the left condyle. Geometric centre of the head of the condyle. Located by visual inspection (Oliceph, 1983).

46. PP1. Palatal point 1:

The most anterior-superior point on the inferior outline of the hard palate. Located by projecting onto the inferior outline of the palatal contour the bisector of the angle formed between the posterior palatal plane and the anterior palatal plane. The posterior palatal plane is selected by visual inspection to represent the inferior surface of the posterior hard palate. The anterior palatal plane is selected by visual inspection to represent the slope of the inferior surface of the anterior palatal contour in the vicinity of the rugae (Oliceph, 1983).

47. PP2. Palatal point 2:

The posterior intersection of a 5 millimetre arc from PP1 with the inferior outline of the hard palate (Oliceph, 1983).

48. PP3. Palatal point 3:

The anterior intersection of a 5 millimetre arc from PP1 with the inferior outline of the hard palate (Oliceph, 1983).

49. D Point:

The geometric centre of the bulbous portion of the symphysis as seen on a lateral cephalometric radiograph. Located by visual inspection (Steiner, 1953).

50. MC60. Mandibular Corpus 60 millimetre point:

The intersection of a 60 millimetre arc from D Point with the inferior aspect (average of left and right sides) of the mandibular canal (Oliceph, 1983).

POINTS 51-64 are needed for the DENTAL CAST TECHNIQUE. These were digitized randomly in the bottom corner of the digitizing pad as they were not used in this study, but were needed by the OlI programme to analyse the cephalogram.

65. Soft tissue Point Nasion:

The point where the Sella-Nasion line crosses the soft tissue profile (Holdaway, 1983; Oliceph, 1987).

66. Soft tissue Point A:

The soft tissue point overlying the skeletal Point A previously described (Holdaway, 1983; Oliceph, 1987).

67. Soft tissue Point B:

The soft tissue point overlying the skeletal Point B previously described (Holdaway, 1983; Oliceph, 1987).

68. WITS Premolar point on Functional Occlusal Plane:

Location by inspection of a point on the occlusal plane where the premolars occlude (Jacobson, 1975; Oliceph, 1987).

69. WITS Molar point on Functional Occlusal Plane:

Location by inspection of a point on the occlusal plane where the molars occlude (Jacobson, 1975; Oliceph, 1987).

70. Upper incisor buccal point:
Most anterior point on the buccal surface of the upper central incisor (Holdaway, 1983; Oliceph, 1987).

3.3.2 Definitions of the variables measured

The various linear and angular cephalometric measurements are described in Figures 15, 16, 17 and 18. These figures represent the analyses included in the Oliceph cephalometric computer programme. The variables are defined in the corresponding chapters.

3.3.3 Radiographic technique

The lateral cephalograms used in this study had to be obtained from different orthodontic offices in order to fulfil the requirements of the sample size of this project. The cephalograms were, however, all taken by radiographers familiar with the technique. The enlargement factor for each x-ray machine was calculated.

3.3.3.1 The cephalometric radiograph

The lateral cephalometric x-ray film was taken with the subject's head held in a commercial cephalostat and exposures were made. The target to film distance was standardized at 152,4cm (five feet). The left side of the subject's head was positioned against the film cassette. All subjects were x-rayed with their teeth fully occluded and with the mid-sagittal plane perpendicular to the floor and the Frankfurt horizotal plane parallel to the floor. The lips were held together.

Three cephalometric radiographs were necessary in order to determine the longitudinal dentofacial changes. The pre-treatment (T1) and post-treatment (T2) cephalometric radiographs were part of the active orthodontic treatment. Special permission was granted by the Ethical Committee of the University of Stellenbosch to attain the post-orthodontic (T3) cephalometric radiograph. This permission was granted on the basis that:

i) a study of this magnitude has not previously been performed on a South African sample,

ii) certain dental adjustments were to be executed during this post-orthodontic period which included interproximal approximation, fitting of spring retainers, sectional bandings and also the removal of third molar teeth, and

iii) the subjects included in the sample were informed regarding the purpose of the project and given the opportunity to refuse should they not want to be futher exposed to any x-rays.

3.3.3.2 Enlargement error

The radiographic image is always larger than the original subject due to the inherent property of x-rays to proceed in radiating straight lines from the anode (Thurow, 1977). Enlargement factors become meaningful when the linear error exeeds the limit of what is considered acceptable, which limit depends on the natural variation in the size of the anatomic region being studied. The sample in this study consisted of subjects of various ages and sizes which means that the enlargement factor could not only have varied from subject to subject and from age-group to age-group, but could also have varied between the different x-ray machines. Midline cranial structures would tend to be slightly further away from the film when comparing a young small head to an older, bigger head on a radiograph. It was thus deemed necessary to calculate an average enlargement factor for the purpose of accurate measurements. The enlargement correction of 7,5% was applied to all the measurements on the lateral cephalometric radiographs.

3.3.3.3 Calculation of the enlargement factor

A 100 millimetre radiopaque magnification scale of stainless steel was positioned in the midsagittal plane vertically and parallel to the film plane and a radiograph was taken. The dimension of the scale was periodically checked during this procedure with the same vernier caliper (Sylvac digital vernier caliper) used to measure the plaster casts. The percentage enlargement for the cephalometric set-up was calculated by determining the mean size increase of the images of the magnification scale as seen on the resultant radiographs. The enlargement factor was found to be 7,5% which is in accordance with acceptable norms found with most conventional cephalometers (Broadbent et al.,1975). Björk (1947) described the difficulty of calculating, with accuracy, measurements of diagonal linear distances traversing different sagittal planes. The present study utilised, amongst others, midline sagittal points and this, combined with the fact that the minimum practical object-film distance was used, ensured relative accuracy of the measurements made on these films. In the instances where bilateral landmarks were used, the mid-values between measurements made on the left and on the right images were used (Bergersen, 1980).

In addition to the mensuration of the study casts and cephalometric radiographs, a simple assessment was done of the third molar status. The type of retention appliance utilised following the active treatment was noted.

3.4 Third molars present post-retention

The presence of third molars was noted in order to assess the possible influence they may have had on the stability and alignment of the dental arches. The mode of treatment (extraction or nonextraction) was also studied in this context.

3.5 Retention appliances

The types of retention appliances used were noted as well as the period of the time these were in place following active treatment. The purpose of this observation was to evaluate not only the long-term stability post-retention, but to assess the changes that took place during the retention phase.

3.6 Intra-observer error

The degree of intra-observer variation was calculated. Measurements of ten sets of study models and ten cephalograms were repeated at three different intervals, on separate days, without reference to prior measurements. These study records, as well as the variables measured, were randomly selected from the sets of records available in the sample. Descriptive statistics of the data are set out in Table III. The Wilcoxon signed-rank test (nonparametric statistics) was used to evaluate the significant differences between measurements (Table IV).

The study model variables were:

a) mandibular intercanine width in millimetres, buccal measurement (L3-3B) and incisal measurement (L3-3I) (Fig. 9),

b) maxillary intermolar width measured in millimetres, mesiobuccal measurement (U6-6B) and mesiobuccal incisal measurement (U6-6I) (Fig. 10), and

c) arch length in millimetres, conventional (ARCHL) (Fig. 13) and described by Little (1990) (LITTLE-A) (Fig. 14).

The cephalometric variables were:

(FMA) (Tweed, 1954). Similar to Go'Gn' to FH in figure 16,

b) facial angle measured in degrees (FAC-ANGL) (Ricketts, 1981) (NPo to FH, Fig. 16),

c) facial-axis angle measured in degrees (FAC-AXIS) (Ricketts, 1981) (PtGn' to NBa, Fig. 16),

d) facial taper or chin button taper measured in degrees (FAC-TAPER) (Ricketts et al., 1979) (N-Gn'-Go', in Fig. 16),

e) mandibular arc measured in degrees (MAND-ARC) (Ricketts, 1981) (PM-Xi to Xi-DC, Fig. 16),

f) lower facial height measured in degrees (L-FACH) (Ricketts, 1981) (ANS-Xi-PM, Fig. 16),

g) the maxillary convexity at point A measured in millimetres (A-CONVEX) (Ricketts, 1981; Holdaway, 1983) (A to NPo, Fig. 16 or A Point Convexity, Fig. 18),

h) mandibular incisor position to point A-Pogonion line, angular (/I-APO-DEG) and millimetres (/I-APO-MM) (Ricketts, 1981) (Fig. 16),

i) maxillary molar position measured in millimetres between pterygoid vertical (PTV) and distal aspect of the upper first molar (UM-PTV-MM) (6/ to PTV, Fig. 16), and between the centre of the face (CCV) and the distal of the upper first molar (UM-CCV-MM) (Ricketts et al., 1979), and

j) lower lip to E-plane measured in millimetres (L-LIPE-MM) (Ricketts, 1981) (/M lip to E, Fig. 16).

TABLE III

DESCRIPTIVE STATISTICS OF INTRA-OBSERVER ERROR CALCULATION

	1		2		3	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
L3-3I	27.07	0.97	27.07	1.06	26.96	0.97
L3-3B	31.39	1.13	31.32	1.23	31.38	1.03
ARCHL	22.74	3.08	22.73	3.11	22.71	2.91
LITTLE-A	59.31	5.73	59.16	5.69	59.18	5.70
U6-6I	52.05	2.19	52.09	2.22	52.00	2.22
U6-6B	54.78	2.22	55.03	2.19	55.03	2.20
FMA	18.45	4.74	18.62	5.39	18.93	5.17
FAC-ANGL	91.04	2.64	90.96	2.61	91.11	2.65
FAC-AXIS	88.76	2.75	88.79	2.82	88.88	2.71
FAC-TAPE	70.08	4.99	69.97	5.60	69.48	5.32
MAND-ARC	34.47	5.45	35.05	5.20	34.42	5.48
L-FACH	42.95	2.33	42.96	2.44	42.72	2.15
A-CONVEX	2.14	3.47	2.13	3.49	2.15	3.55
/I-APO-MM	1.34	1.89	1.39	1.89	1.65	2.06
/I-APO-DEG	30.53	4.66	30.77	5.15	29.64	6.09
UM-PTV-MM	19.94	3.71	20.36	4.17	20.52	3.66
UM-CCV-MM	18.68	3.85	19.07	4.34	19.17	3.69
/M-LIPE-MM	-0.45	3.69	-0.81	3.81	-0.72	3.67

S.D. = Standard deviation
1, 2, 3 = Measurements of variables repeated three times

TABLE IV

LEVEL OF SIGNIFICANCE (p) OF WILCOXON SIGNED RANKS TO INDICATE DIFFERENCES BETWEEN MEASUREMENTS REPEATED THREE TIMES TO TEST FOR INTRA-OBSERVER ERROR

VARIABLE: L3-3I

	1	2	3
1	1.00		
2	0.41	1.00	
3	0.03	0.07	1.00

VARIABLE: L3-3B

	1	2	3
1	1.00		
2	0.51	1.00	
3	0.72	0.92	1.00

VARIABLE: ARCHL

	1	2	3
1	1.00		
2	0.77	1.00	
3	0.79	0.88	1.00

VARIABLE: LITTLE-A

	1	2	3
1	1.00		
2	0.51	1.00	
3	0.17	0.59	1.00

VARIABLE: U6-6I

	1	2	3
1	1.00		
2	0.68	1.00	
3	0.72	0.19	1.00

VARIABLE: U6-6B

	1	2	3
1	1.00		
2	0.08	1.00	
3	0.17	0.48	1.00

VARIABLE: FMA

	1	2	3
1	1.00		
2	0.14	1.00	
3	0.15	0.23	1.00

VARIABLE: FAC-ANGL

	1	2	3
1	1.00		
2	0.06	1.00	
3	0.67	0.16	1.00

VARIABLE: FAC-AXIS

	1	2	3
1	1.00		
2	0.87	1.00	
3	0.31	0.61	1.00

VARIABLE: FAC-TAPE

	1	2	3
1	1.00		
2	0.17	1.00	
3	0.14	0.11	1.00

VARIABLE: MAND-ARC

	1	2	3
1	1.00		
2	0.33	1.00	
3	0.72	0.68	1.00

VARIABLE: L-FACH

	1	2	3
1	1.00		
2	0.95	1.00	
3	0.37	0.39	1.00

VARIABLE: A-CONVEX

	1	2	3
1	1.00		
2	1.00	1.00	
3	0.94	0.86	1.00

VARIABLE: /I-APO-MM

	1	2	3
1	1.00		
2	0.61	1.00	
3	0.06	0.19	1.00

VARIABLE: /I-APO-DEG

	1	2	3
1	1.00		
2	0.72	1.00	
3	0.31	0.20	1.00

VARIABLE: UM-PTV-MM

	1	2	3
1	1.00		
2	0.14	1.00	
3	0.01	0.20	1.00

VARIABLE: UM-CCV-MM

	1	2	3
1	1.00		
2	0.16	1.00	
3	0.02	0.24	1.00

VARIABLE: /M-LIPE-MM

	1	2	3
1	1.00		
2	0.04	1.00	
3	0.16	0.48	1.00

p = Level of significance, 0.05

No significant difference could be shown between the variables measured except for the following four, intercanine width (L3-3I), upper first molar position (UM-PTV-MM and UM-CCV-MM) and lower lip position (L-LIPE-MM). For L3-3I, UM-PTV-MM and UM-CCV-MM there were significant differences between 1 and 3, and for L-LIPE-MM a significant difference existed between measurement 1 and 2. When the mean values of these differences were observed, it became apparent that the differences although significantly different, would from a clinical point of view not influence the interpretation of the data. In every instance the intra-operator error was less than 1,0% of the value of the parameter being studied except where one of the measurements was different from the other two as previously mentioned. The landmarks of these four variables were difficult to pinpoint and thus extreme care was taken with its assessment. Having determined the intra-operator error, it became clear that it was a sensible decision to measure more than one variable of similar description.

It was thus concluded that intra-operator errors did not have a material effect on the outcome of the present study.

3.7 Statistical analysis of data

All analyses of the present data utilised the SAS (Statistical Analysis System, University of North Carolina, USA, 1985) programs available at the Institute for Biostatistics, Medical Research Council, Tygerberg, Republic of South Africa.

The subjects comprising the sample in this study were of different ages while undergoing, having completed orthodontic treatment or being re-examined for post-treatment changes. A varying number of variables were recorded during the study at the pre-treatment, post-treatment and post-orthodontic time intervals. During the data reduction inferential testing was deemed nescessary in order to evaluate the numerous longitudinal changes that took place during the time span of the study.

3.7.1 Descriptive Statistics

Descriptive statistics were calculated for the complete sample, as well as for males and females, and extraction and nonextraction groups separately. The following statistics were calculated:

1. Mean.
2. Standard deviation.
3. Minimum and maximum range.

3.7.2 Inferential Statistics

More complex analyses were necessary in order to characterize the differences between the pre-treatment (T1) and post-treatment (T2) orthodontic records, and between the post-treatment (T2) and post-orthodontic (T3) orthodontic records. The Friedman test, Wilcoxon test, Chi-square test and Spearman Correlation coefficient test were performed in order to make the necessary conclusions regarding these different orthodontic changes (Zar, 1984). These tests were performed at a significance level of $p = 0.05$.

CHAPTER 4

LONGITUDINAL CHANGES IN THE NASOMAXILLARY COMPLEX AND ITS RELATIONSHIP TO LOWER INCISOR IRREGULARITY

4.1 Introduction

For as long as orthodontics has been a dental speciality a significant problem facing the orthodontist has been the relapse of carefully treated and well finished dentitions (Hellman, 1940; Hahn, 1944; Nance, 1947). The orthodontic literature suggests that correct diagnosis and properly developed treatment plans, followed by execellent mechanotherapy designed to place the teeth in certain predetermined positions, in its turn followed by retention for a certain amount of time, minimizes or eliminates relapse (Behrents, Harris, Vaden, Williams and Kemp, 1989). Stark reality, however, suggests that over two-thirds of orthodontically treated subjects have unacceptable dental alignment 10-20 years following orthodontic therapy (Bell, Proffit and White, 1980; Little, Riedel and Artun, 1988). Less relapse has been documented in other studies , but none the less relapse is a universally accepted phenomenon and problem (Sadowsky and Sakols, 1982; Sandusky, 1983; Uhde, Sadowsky and BeGole, 1983).

It has been suggested that relapse is under the influence of evolutionary or genetic control, such that a certain amount of relapse is inevitable and should be expected during development. There is, however, little scientific evidence to support this point of view (Chung, Niswander, Runck, Bilben and Kay, 1971; Corruccini and Potter, 1980; Harris and Smith, 1980; Harris and Johnson, 1991). In spite of all attempts to control and limit relapse it is probably still true that we are almost complete ignorant of the etiological factors which cause relapse (Behrents et al., 1989). Other schools of thought are based on various clinically-derived guidelines (Strang, 1949; Tweed, 1954; Mills, 1967; Williams, 1985). These guidelines suggest that relapse can be controlled if certain aspects of active treatment are controlled and adhered to. Failure to do so will be prejudicial toward stability. Whatever the cause, malocclusion is an important problem in our dentally aware contemporary society. Although it is difficult to know the precise aetiology of any specific malocclusion, certain general possibilities are known (Proffit, 1986).

There appears to be a fairly strong association ($r = 0.53$) between the irregularity index and the space analysis of Merrifield (1978). This relationship was shown to be sensitive to different occlusal parameters (Harris, Vaden and Williams, 1987). It must be noted, however, that no dental or skeletal parameters appear to correlate with observed post-treatment relapse (Shields, Little, Chapko, 1985; Little, Riedel and Artun, 1988). Similar conclusions have been made for dental changes seen in untreated individuals (Carmen, 1978).

Growth of the craniofacial skeleton has been implicated as a possible factor involved in post-treatment relapse (Litowitz, 1948; Huckaba, 1952; Kelly, 1959; Björk and Skeiller, 1972; Behrents, 1984; Behrents et al., 1989). A statistically significant correlation was reported to exist between the maxillary length (Sella-A Point distance) and the crowding of the lower incisors. It was observed that the Little Irregularity Index decreased with an increase in the maxillary length (Little, 1975; Behrents et al., 1989).

The suggestion is that relapse may occur as a result of tooth movement which occurs as part of the growth process. It is therefore imperative to understand not only treatment effects on the dentitions, but also the anatomy and normal growth changes of the craniofacial components. These factors must be taken into consideration when attempting to study post-orthodontic relapse of the dentition.

4.2 The Nasomaxillary complex and related anatomy

The midface consists of the orbits and their contents, the nasal structures, the maxillary sinuses and alveolar processes and the teeth (Graber 1966).

The largest, and probably the most important, bone in the upper face is the maxilla. It consists of a body and the frontal, zygomatic, alveolar and palatine processes. Other contributions to the face are made by the nasal, frontal, ethmoidal, vomer, lacrimal, conchae, palatine and zygomatic bones.

The intricate anatomical structure of the nasomaxillary complex can be appreciated when the related anatomy of the various surfaces of the maxilla are studied (Van Rensburg, 1981; Longmore and McRae, 1985; DuBrul, 1988).

The anterior surface of the maxilla shows the undulating ridges of the alveolar process formed by the roots of the maxillary teeth, the most prominent being that formed by the canine teeth. The inferior border is formed by the alveolar process which carries the teeth, the medial ridge ends in the anterior nasal spine (ANS), the lateral border, as seen in the anterior view, is the zygomatic process while the superior border follows the infra-orbital ridge cranially to the frontal process.

The posterior surface is laterally related to the infra-temporal fossa and medially to the pterygo-palatine fossa. The infra-temporal surface contains various small foramina allowing the posterior superior alveolar nerves and blood vessels to reach the molar teeth. The maxillary tuberosity, which articulates with the pyramidal process of the palatine bone, is found at a more inferior level. The palatine bone is wedged between the tuberosity and the pterygoid process of the sphenoid bone.

The nasal surface of the maxilla has the opening of the maxillary sinus which is overlapped posteriorly by the vertical plate of the palatine bone. The lacrimal bone closes the sinus anteriorly and superiorly. The lacrimal groove is formed by this articulation between lacrimal bone and maxilla. Superiorly, the ethmoid labyrinth also helps with the sealing of the maxillary sinus. Inferiorly, the sinus is closed by the inferior concha. The middle meatus receives the opening of the sinus.

The orbital surface of the maxilla forms the greater part of the floor of the orbit. The frontal process runs upwards and articulates with the frontal bone superiorly, the nasal bone anteriorly and the lacrimal bone posteriorly. The lacrimal fossa, housing the lacrimal gland, is found on the orbital surface of the frontal process of the maxilla, partly on the maxilla and partly on the lacrimal bone.

The zygomatic process articulates with the zygomatic bone while the alveolar processes form the dental arch which houses the maxillary teeth.

The palatine process, pointing in a medial direction, forms two thirds of the hard palate. The two palatine processes puberty. The anterior part of this groove leads to the incisive foramina found posterior to the incisor teeth. The greater palatine artery passes from the mouth to the nose, and the terminal branches of the nasopalatine nerve and blood vessels from the nose to the mouth, through these foramina. A groove from the incisive foramina runs through the interdental space between the lateral and canine teeth on both sides of the maxilla, in the young skull, separating the premaxillary part from the main body of the maxilla. The very intricate nature of the anatomy of the nasomaxillary complex is emphasised by its attachments to the various bones noted. According to Brodie (1940b, 1941, 1953) the sutures involved in attaching the mid-face to the cranium, are all orientated in such a way that growth at these sutures results in a downward and forward movement of the midface. The sutures are:

i) Fronto-maxillary
ii) Zygomatico-temporal
iii) Zygomatico-maxillary
iv) Pterygo-palatine

This alignment allows the midface to maintain its antero-posterior relationship to the growing anterior cranial base and at the same time increase its vertical dimension. The growth is excellently illustrated and documented in the literature (Riolo et al., 1974; Broadbent, Broadbent and Golden, 1975; Behrents, 1984).

It was thought for many years that primary growth occurred at these sutures in the midface. It has, however, not been possible to demonstrate autonomous expansive growth of these sutures, nor the perfect alignment of them for the growth needed. This theory thus fell away. Today the sutures are seen as areas of adaptive growth and are described as being "growth adjusters" rather than "growth initiators" (Coben, 1955; Ranly, 1980).

4.3 Theories of Nasomaxillary complex growth

Various hypotheses in respect of nasomaxillary growth have been developed in order to assist clinicians in their quest for excellent orthodontic diagnosis and treatment. Exactly what determines the growth of the jaws remains largely unclear. The following theories attempt to give some insight into this complex growth process.

4.3.1 Sicher and Brodie's theory

In Sicher and Brodie's view all bone forming elements (cartilage, sutures and periosteum) are growth centres (Ranly, 1980). The "theory of sutural force" was developed because bone is pressure sensitive. Different researchers including Enlow (1968) proposed that myofibroblasts in the sutures are responsible for producing a type of joint which creates an action causing slippage of bones separated by sutures and due to the tension of the myofibroblast on the bone margins, growth occurs in the sutures.

They claimed that the nasomaxillary complex grows forwards and downwards due to active growth of the fronto-nasal, zygomatico-maxillary, zygomatico-temporal, and pterygo-palatine sutures. They described these sutures as centres of active growth. Brodie found that certain anatomical planes are in constant correlation with each other throughout growth e.g. the mandibular, palatine and occlusal planes and the skeletal base.

The theory does not seem to apply in cases of hydrocephaly where if the sutural growth was genetically determined then the calvarium would not cover the rapidly expanding cranial contents.

4.3.2 The nasal septum growth theory

Scott (1948, 1953) introduced the "nasal septum growth theory". He claimed that cartilage is specially developed to produce pressure while growing at the same time. Although the nasal cartilage provides only a small part of the endochondral growth of the skull, it forms the basis for the above theory. Accordingly expansion of the nasal cartilage produces pressure which initiates growth in the maxillary sutures.

This theory classifies cartilage areas (especially nasal) as growth centres and classifies sutures as being passive and secondary growth areas (Ranly 1980). Accordingly, the spheno-ethmoidal, palato-maxillary and pterygo-palatine sutures form part of the intregal circum-maxillary suture systems which makes it possible for the nasal cartilage to push the maxilla away from the sphenoid bone. It is claimed that this whole system stops growing at seven years of age which becomes the end of the first phase of growth. The second phase of growth is said to commence after 7 years of age (Scott, 1953).

Removal of the nasal septae of animals results in underdevelopment of the nasomaxillary complex. Such animal experiments attempt to prove the importance of the nasal septum as a growth centre (Sarnat and Wexler, 1966). Koski (1968) claimed that there was general consensus concerning the role of the cartilaginous nasal septum in providing a thrusting force which carries the maxilla forwards and downwards during growth. Storey (1972) suggested that failure of the nasal cartilage to grow normally results in a lack of maxillary growth with the resultant development of a Class III jaw relationship. The importance of the nasal septum is not so much that it is a growth centre which controls the forward growth of the maxilla, but that it is an important growth point (Babula, Smiley and Dixon, 1970). On the other hand the potential of the septum to act as a growth centre is linked to the growth potential of the cartilage cells, which are genetically programmed and which will respond to various demands.

Experimental excision of the nasal septum markedly affects the growth of the upper face. Such experiments are not conclusive as the malformations which result could also be due to the surgical procedures.

Observations in children with agenesis of the nasal septum indicates that the septum is important for antero-posterior growth of the upper face, presumably because of endochondral growth occurring at its posterior border, but not for vertical development of the face.

On the basis of all the evidence it may be concluded that the septo-ethmoidal junction acts as a growth centre during postnatal life (Ranly, 1980).

In summary, Scott (1953) claimed that the soft tissues of the face keep pace with the sutural separation achieved by the enlarging nasal septum. Thus as the bones of the midface move ahead of the expanding septum, corresponding additions of bone at the various facial sutures passively function to maintain the bones in continuous sutural contact and to enlarge them in a linear manner.

4.3.3 The septo-premaxillary ligament theory

The nasal septum lies inferiorly in the vomerine groove, separated from the vomer by a fat layer. Anteriorly the septum is attached to the premaxilla in the area of the nasal spine by a "fibrous tissue" (septo-premaxillary ligament) (Latham, 1969, 1970). This fibrous ligament is said to extend from the antero-inferior border of the nasal septum in a postero-inferiorly direction to the anterior nasal spine (ANS) and the intermaxillary suture of the premaxillary region.

It is claimed that the nasal septum and the fibrous septo-premaxillary ligament, in prenatal and in early postnatal maxillary growth, has an influence on the direction of facial growth (Latham, 1969, 1970).

Latham claims two mechanisms which affect growth of the naso-maxillary complex:

i) In foetal life the pull of the septo-maxillary ligament.

ii) In post-natal life the maxilla has the intrinsic capability to remodel itself in an upwards and backwards direction.

Studies in experimental animals show that severing the septo-premaxillary ligament retards maxillary growth relative to the rest of the cranium (Gange and Johnson, 1974). These authors postulate that in future the severing of this ligament may be of clinical importance in treating Class II malocclusions.

4.3.4 Moss's Functional Matrix theory

This theory (Moss, 1962) claims that bone grows in response to the sum of the accumulated forces placed on it by the expansion of the soft tissue surrounding it. The theory claims equal importance for cartilage and sutures in craniofacial growth.

Accordingly no one entity such as the nasal septum, has the ability to move a complex structure such as the mid-face. Nasomaxillary growth results in an expansion of the facial muscles, subcutaneous, and submucosal tissue, oral and nasal epithelium as well as blood vessels and nerves.

The question as to whether the functional matrix theory and the concept of nasal septum growth can be combined has not been answered (Ranly, 1980). Speculation on whether the nasal cartilage controls the growth of the midface or whether the cartilage is controlled by means of a capsular matrix remains contentious.

4.3.5 Theory of genetic influence

This is basically a combination of Scott's and Moss's theories and is possibly the most accepted one. Local epigenetic factors (brain and eyes) appear to play an important role according to this theory which suggests that skull growth is under genetic influence (Van Limborgh, 1970).

4.3.6 A modern composite (Ranly 1980)

The development of the nasomaxillary complex can be influenced by a wide range of factors including developmental abnormalities, postural pressure during pregnancy, pressure of the birth canal, familial genetic factors, and environmental factors such as trauma, loss of teeth, caries, muscle function and habits.

4.4 Dimensional changes of the Nasomaxillary complex during growth

Dimensional changes must be studied in subjects who have not undergone orthodontic treatment in order to assess normal longitudinal growth changes. These changes will enable orthodontists to distinguish between treatment and other influences on occlusal stability.

Normal growth of the nasomaxillary complex is well described in the literature (Enlow, 1968; Proffit, 1986; Moyers, 1988). Some of these growth changes are set out in Table V, VI and VII (Adapted from Riolo, Moyers, McNamara Jr. and Hunter, 1974).

4.5 Treatment effects on growth of the Nasomaxillary complex

Treatment can lead to positional change in some of the facial landmarks. During a description of the use of the visual treatment objective (VTO), the examples were given for changes in point A as a result of various treatment procedures (Ricketts et al., 1979):

Mechanics	Movement caused
i) Headgear	- 8mm
ii) Class II elastics	- 3mm
iii) Activator	- 2mm
iv) Torque	- 1-2mm
v) Class III elastics	+ 2-3mm
vi) Facial Mask	+ 2-4mm

TABLE V

AGE RELATED MEAN VALUES OF CERTAIN MAXILLARY DIMENSIONS FOR MALES AND FEMALES

Male / **Female**

Sella-Nasion-A point (SNA) (Population sample from Riolo et al., 1974):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
6	37	81.9	3.3	6	25	80.7	3.0
10	46	80.8	3.1	10	35	80.7	3.7
13	43	81.2	3.4	13	29	81.0	3.8
16	23	81.4	4.4	16	9	81.8	3.7

Sella-Nasion-Basion (SNBa) (Population sample from Riolo et al., 1974):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
6	37	129.3	5.0	6	25	129.6	5.0
10	46	129.2	4.7	10	35	129.7	4.5
13	43	129.2	5.3	13	29	130.3	4.7
16	23	128.9	5.9	16	9	131.1	4.1

Convexity at point A (Population sample from Ricketts, 1981):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
6	37	5.2	2.3	6	25	4.5	2.2
10	46	3.9	2.5	10	35	3.5	2.8
13	43	3.2	2.6	13	29	2.7	2.6
16	23	2.6	3.4	16	9	1.7	2.9

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE VI

AGE RELATED MEAN VALUES OF THE PALATAL PLANE ANGLE FOR MALES AND FEMALES
(Population sample from Riolo et al., 1974)

Palatal plane angle (ANSPNS-SN):

Male				Female			
Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
6	37	5.2	2.4	6	24	7.0	2.6
10	46	6.1	2.6	10	35	7.5	2.8
13	43	7.1	3.2	13	29	8.2	2.9
16	23	7.0	3.0	16	9	8.0	2.2

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE VII

AGE RELATED MEAN VALUES OF CERTAIN CRANIAL BASE DIMENSIONS FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Sella-Nasion (S-N):

Male Age(X)	N	mm(X)	S.D.	Female Age(X)	N	mm(X)	S.D.
6	37	72.7	2.8	6	25	70.3	2.7
10	46	76.8	3.2	10	35	73.9	2.8
13	43	79.5	3.8	13	29	75.5	3.1
16	23	83.3	3.8	16	9	76.9	3.9

Sella-Nasion/Frankfort plane (SN-FH):

Male Age(X)	N	Degrees(X)	S.D.	Female Age(X)	N	Degrees(X)	S.D.
6	21	6.1	3.0	6	12	6.5	4.7
10	25	5.4	2.7	10	14	6.1	3.9
13	23	4.0	3.6	13	9	6.2	3.3
16	13	3.1	3.6	16	5	4.8	2.9

Sella-Articulare, posterior (S-Ar):

Male Age(X)	N	mm(X)	S.D.	Female Age(X)	N	mm(X)	S.D.
6	37	29.5	2.8	6	25	28.4	3.1
10	45	33.7	3.1	10	35	32.6	3.4
13	43	36.9	3.5	13	29	34.6	3.8
16	23	38.2	3.1	16	9	34.0	2.9

X = Mean
N = Sample size
S.D. = Standard deviation

Positive values (+) indicate protrusive movements and negative values (-) indicate retrusive movements.

Although general orthopaedic responses in the mandible are variable, depending on facial growth type, maxillae tend to respond in a more predictable way to forces directed at a level of, or below, the rotational centre of the maxillae. When a distal force is applied to the maxillary dentition, the maxillary complex rotates in a clockwise direction around a point which roughly approximates the top of the pterygomaxillary fissure. This rotation accounts for a reduction in maxillary protrusion and a downward canting of the palatal plane (ANS-PNS). There is a reciprocal clockwise rotation of the mandible, an opening of the facial axis and the mandibular plane and a retrusive effect on the chin (Ricketts et al., 1979).

The various changes described above could contribute to relapse of a malocclusion following orthodontic treatment.

4.6 Objectives

There exists no longitudinal growth data for the nasomaxillary complex as defined for this or another similar sample (Table I). There is also no data in respect to orthodontic treatment available to enable one to compare the changes occurring in the nasomaxillary complexes of this sample during orthodontic treatment, as well as changes occurring following orthodontic treatment, to other studies noted previously.

Hence, the objectives of this part of the study were:

i) to assess the longitudinal changes occurring in the nasomaxillary complex and cranial base during treatment and growth and,

ii) to determine whether any of these changes affected long-term post-treatment stability of the dentition.

4.7 Materials and methods

The description of the materials used and the methods employed to assess the data are documented in Chapter 3.

For this part of the study the Little Irregularity Index (Little, 1975) was correlated with the cephalometric nasomaxillary dimensions. The Little Irregularity Index provides an indication of the lower incisor crowding and was measured with a digital calipers capable of measuring to 0.01mm (Sylvac S.A., Rue du Jura 2, 1023 Crissier. Switzerland). The cephalometric measurements were obtained with the use of the Oliceph computer programme (Oliceph, Kansas City, Missouri, USA) and for this part of the study comprised the following:

1. The maxillary morphology as described by:
   i) the SNA angle (SNA) (Steiner, 1953).
   ii) the maxillary convexity at point A (A-CONVEX) (Ricketts, 1981).
2. The angle measured between the palatal line (ANS-PNS) and the SN line (ANSPNS-SN).

3. Some cranial base dimensional changes (Bjork, 1947; Jarabak and Fizzell, 1972; Oliceph, 1987). The N-S-Ar angle (SADANGLE), S-N length in millimetres (SN-MM) and the S-Ar length in millimetres (SAR-MM).

4. The angle between the SN line and the Franfkfurt horizontal line (SN-FH) (Oliceph, 1987).

4.7.1 Criticisms of SNA and ANS-PNS

The use of the angle SNA to measure maxillary prognathism has been criticised by a number of authors (Baumrind and Frantz, 1971; van der Linden, 1971; Jacobson, 1975, 1976; Jacobson and Jacobson, 1980). The criticism has been based mainly on problems which may be experienced in locating point A on lateral cephalometric radiographs (Jacobson and Jacobson, 1980). The size of the angle SNA is affected by the cant of the anterior cranial base, as well as by the anteroposterior position of the maxilla relative to the rest of the face (Jacobson, 1975, 1976).

Because the majority of cephalometric analyses use SNA to measure the relative position of the maxilla (Jacobson and Jacobson, 1980), its use has been retained in the present study.

It has been suggested that in a lateral cephalometric radiograph a line through the most radio-opaque outline of the palate may best represent the palatal plane (Jacobson, 1976). This approach is in keeping with Blafer's (1971) contention that the anterior nasal spine has no consistent shape and that its position is quite independent of the horizontal trend of the rest of the palate. In the present study of the palatal plane angle (ANSPNS-SN) the conventional landmarks (ANS and PNS) were, nevertheless, employed to make possible ready comparison with results from previous studies of the palatal plane.

4.8 Results

The findings are set out in Tables VIII and IX.

The pairwise comparisons indicated that SNA remained constant during the post-orthodontic period (T2-T3). A significant change ($p = 0.0001$) was measured, however, for the entire period of the study, being pre-treatment to post-orthodontic time interval (T1-T3). The palatal plane angle (ANSPNS-SN) remained stable from T1-T3. The saddle angle (SADANGLE) and the angle SN-FH showed no significant change ($p > 0.05$) from T1-T3. The convexity measured at point A (A-CONVEX) decreased significantly ($p = 0.0001$) throughout the study (T1-T3). The cranial base length measurements (SN-MM and SAR-MM) also showed a significant change ($p = 0.0001$) from T1-T3, increasing throughout the study (Table VIII).

According to the correlation analysis (Table IX) only the maxillary anteroposterior position (SNA) at T3 showed a weak significant correlation with the Little Irregularity

TABLE VIII

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT TO THE NASOMAXILLARY COMPLEX
(Friedman test included)

	T1		T2		T3			T1-T2	T1-T3	T2-T3
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	p-value	Pairwise differences		
SNA	81.31	3.56	79.55	3.50	80.07	3.53	0.0001	+	+	x
ANSPNS-SN	7.53	2.89	8.17	3.22	7.86	3.21	0.03	-	x	x
SADANGLE	123.48	4.67	123.94	4.82	123.82	5.15	0.34	x	x	x
SN-FH	10.35	2.51	10.64	2.60	10.45	2.73	0.85	x	x	x
A-CONVEX	4.16	2.95	1.98	2.71	1.12	2.99	0.0001	+	+	+
SN-MM	71.84	3.20	73.90	3.30	75.95	4.13	0.0001	-	-	-
SAR-MM	35.02	3.47	36.59	3.49	37.49	3.93	0.0001	-	-	-
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	-	-	-

S.D. = Standard deviation
\+ = Significant, $p < 0.05$ (T1 > T2, T3)
\- = Significant, $p < 0.05$ (T1 < T2, T3)
x = Not significant, $p > 0.05$

TABLE IX

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE NASOMAXILLARY AND CRANIAL BASE DIMENSIONS TO THE LOWER INCISOR IRREGULARITY INDEX AT T3

LOWER IRREGULARITY INDEX (L-IRREG)

	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
SNA	-0.13	0.22	-0.15	0.16	-0.24	0.03
ANSPNS-SN	0.14	0.18	0.15	0.16	0.20	0.06
SADANGLE	0.04	0.69	0.11	0.31	0.10	0.38
SN-FH	0.09	0.42	-0.09	0.38	-0.01	0.92
A-CONVEX	0.04	0.72	0.04	0.75	-0.02	0.84
SN-MM	0.11	0.32	0.09	0.40	0.19	0.07
SAR-MM	0.10	0.36	0.15	0.15	0.11	0.32

r = Spearman correlation coefficient
p = Probability values, Significance level 0.05

Index at T3 ($r = -0.24$; $p = 0.03$). No other significant correlations could be shown with the post-treatment lower incisor irregularity ($p > 0.05$).

4.9 Discussion

Growth (Behrents et al., 1989) and treatment (Gardner and Chaconas, 1976; Little, Wallen and Riedel, 1981) have been shown to affect the stability of the post-treatment occlusion.

The SNA remains basically unchanged during normal growth (Table V). The SNA was reduced during treatment (T1-T2) by 1.76 degrees, but showed a small rebound (relapse) during the post-orthodontic treatment phase (T2-T3) of 0.52 degrees. This rebound was not clinically significant and for all purposes the SNA stayed stable following the active orthodontic treatment (Table VIII).

The dimensions of the anterior and posterior part of the cranial base increase in length during normal growth, but this increase does not influence the cranial base angle (angle BaSN) and the palatal plane angle which remain basically unchanged (Tables V, VI and VII). Similar data was recorded during orthodontic treatment. The palatal plane angle (ANSPNS-SN), the cranial base angles (NSAR, SADANGLE) and the angle between the cranial base reference lines, Sella-Nasion (anterior cranial base) and Frankfurt horizontal (SN-FH) remained virtually constant from T1-T3 ($p > 0.05$) (Table VIII). It appears that cranial base changes had little, if any, effect on the degree of post-treatment relapse. The stable palatal plane angle (ANSPNS-SN) following orthodontic treatment indicates a high degree of vertical control of the maxillary position during the use of Class II and Class III orthodontic mechanics. Class II and Class III intermaxillary traction are necessary to enable the orthodontist to correct anteroposterior occlusal and midline discrepancies, and to enhance anchorage requirements when indicated.

Convexity at point A (A-CONVEX) was reduced concomitant with the reduction of the angle SNA (T1-T2), but the convexity continued to decrease following the removal of active appliances (T2-T3). The reduction from T2-T3 could be classified as part of normal growth as is indicated in Table V, and may in part have been due to growth at the mandibular symphysis. Mandibular growth causes the facial plane angle (Ricketts et al., 1979) to increase. The facial plane thus moves anteriorly as a result of this growth, more at the chin (the mandible normally grows in a forwards and closing rotational direction (Tables X and XI)) than at the maxilla measured at point A, which results in a reduction of the convexity at point A. The significant reduction of the SNA angle during treatment (T1-T2) and the consistency of this angle following active treatment (T2-T3) (Table VIII), in accompanyment with late forward growth of the mandible (T2-T3) (SNB, SND, FAC-ANGLE, FAC-AXIS, Table XVI) may have contributed to the post-treatment lower incisor crowding as measured by the increase in the Little Irregularity Index (Table VIII). This observation would be in agreement with the findings of Behrents et al. (1989) who showed that lower incisor crowding is less in subjects in whom the maxillary length (measured from Sella to point A) increased after orthodontic treatment.

The anterior, (SN) and posterior (SAR) cranial base lengths continued to increase during the study (T1-T3). These dimensions increased as a result of normal growth of the cranial base (Table VII) which has the nasomaxillary complex attached to its anterior component. It could be speculated that although these dimensions increased (T1-T3), the forward growth of the mandible was greater than that of the maxilla as witnessed by the decrease of the convexity measured at point A (Table VIII).

The changes which took place as a result of treatment (T1-T2) remained largely stable during the follow-up period (T2-T3) which had a mean duration of nearly seven years. Growth changes are reflected in Table VIII. During the active treatment period (T1-T2) it is difficult to distinguish growth changes from that occuring as a result of treatment, but during the post-orthodontic period (T2-T3) mostly growth and maturity changes (Behrents, 1984) occur and it is possible that these growth changes could contribute to relapse incidences.

4.10 Conclusions

1. There was a reduction of the SNA angle as a result of

the orthodontic treatment (SNA decreased and SNB remained practically constant), suggesting a more retrusive maxillary anteroposterior position which could in turn contribute to lower incisor crowding in the post-orthodontic period.

2. Maxillary retrusion in combination with forward growth of the mandible, partially borne out by a continued reduction of the convexity at point A, could enhance post-treatment crowding of the lower incisors.

3. Retrusion of point A during treatment must be done with due consideration being given to mandibular growth (as well as to upper incisor torque).

CHAPTER 5

LONGITUDINAL CHANGES IN THE MANDIBLE AND ITS RELATIONSHIP TO THE STABILITY OF ORTHODONTICALLY TREATED DENTITIONS

5.1 Introduction

The morphology of the face as a whole, as well as of its component parts, largely determines the direction which will be taken by the face during growth (DuBrul, 1988). The writings of Brodie (1941, 1953), Björk (1947), Lande (1952), Behrents (1984) and Behrents et al. (1989) indicate that the success or failure of a treated malocclusion may be influenced by growth.

Extreme mandibular rotation (Björk, 1969) and complicated facial development (Björk and Skieller, 1972) may be responsible for increased lower arch crowding. Late lower arch crowding is also claimed to be caused by a specific pattern of growth and a type of skeletal pattern which is susceptible to crowding at the beginning of adolescence (Sakuda, Kuroda, Wada and Matsumoto, 1976). Mandibular growth, which occurs predominantly by downwards and forward (protrusive) mandibular rotation, is thought to be a factor which could contribute to late crowding of the lower anterior teeth (Richardson, 1986).

Changes in the shapes and positions of the jaws are mostly dependant on growth (Holdaway, 1956). Holdaway believed that when treatment reduced the size of the angle ANB, most of the change was due to the angle SNA becoming more acute. This was the result of an inhibition of maxillary alveolar growth and a change in the position of point A as a result of the upper incisors being retracted. In most cases, even when favourable mandibular growth was observed, the angle SNB became only slightly more obtuse, or remained static. This finding can be attributed to a bite opening movement due to orthodontic treatment or to lingual movement of the lower incisors which can alter the relationship of point B to the body of the mandible.

Growth also tends to cancel out some of the unfavourable side effects which result from wearing orthodontic appliances. For example the simple placing of fixed appliances may cause teeth to extrude sligthly from their alveolar processes (King, 1960). The flattening of the curve of Spee during orthodontic treatment and most Class II treatment modalities may cause further dental extrusion. In nongrowing patients the nett effect of this was to cause the mandible to tip downwards which in turn caused pogonion to move posteriorly relative to the anterior cranial base. With active growth, however, many of the unfavourable side effects of the appliances could be corrected by the growth, while in some instances, growth made the situation worse. If the mandible does swing downwards as a result of treatment, forward growth following the therapy could result in a recovery of the mandibular position (King, 1960). If this downwards tipping of the mandible occurred in the absence of growth, subsequent recovery after treatment could contribute to some unfavourable sequelae such as incisor crowding (King, 1974).

In theory, with a forward displacement of the mandibular symphysis as a result of growth, as indicated by the SNB angle becoming more obtuse, the lower incisors may be placed forwards relative to the upper incisors. This change is resisted by the lower incisors occluding with the upper incisors and which may result in crowding of the mandibular incisors (Perera, 1987).

Increased lower dental crowding has been reported following active orthodontic treatment (Haavikko and Bäckman 1973; Shapiro 1974; Little, Wallen and Riedel, 1981; Rönnerman and Larsson 1981; Little, 1990). Similar findings were also reported in untreated normal subjects (Sinclair and Little, 1983).

In order to study the effects on the dentition of mandibular dimensional changes during and following orthodontic treatment an understanding of the intricate anatomy and growth changes of the mandible is necessary.

5.2 The mandible and related anatomy

Each half of the mandible develops in membrane from a single centre which is formed in the first pharyngeal (mandibular) arch on the outer side of Meckel's cartilage. Meckel's cartilage, by the sixth week, extends down from the otic capsule to meet its other half in the midline of the foetal face. At birth the mandible consists of two halves joined at the symphysis by cartilage and fibrous tissue. At this stage the mandible differs in some respects from its adult appearance in that the body has a large alveolar component full of unerupted deciduous teeth. This results in the mandibular foramen lying close to the inferior border. As the permanent dentition is established the foramen moves to a higher position halfway between the upper and lower border. During the first year of life the two halves fuse. The other secondary cartilages present at birth are the bilateral coronoid and condylar cartilages. The coronoid catilage become ossified during the first year of life. The condylar cartilage which appears in the twelfth intra-uterine week, above and lateral to the bony part of the condylar process, forms a conical mass which is gradually replaced by bone by about the fifth month. A zone of cartilage is, however, left beneath the articular surface of the condyle which allows for limited growth of the mandible as well as for moulding of the condyle to fit the articular area on the growing temporal bone (Longmore and McRae, 1985).

The mandible forms the lower part of the skeleton of the face and carries the mandibular teeth. Unlike the other skull bones, it is mobile and consists of a horseshoe-shaped body and each half has a ramus. The mandible gives insertion and origin to some important muscle groups, notably the muscles of mastication and of the tongue

(Longmore and McRae, 1985; DuBrul, 1988). The upper end of the ramus is divided into the condylar and coronoid processes by the sigmoid notch. The condylar process has a constricted part, the condylar neck which carries the condyle with its articular surface (DuBrul, 1988).

In growing children the mandible appears to grow essentially downwards and forwards. Vital staining experiments (Brash, 1924) as well as the recognition of condylar growth centres (Charles, 1925; Brodie, 1941) have shown that the predominant direction of mandibular growth is actually posteriorly. It is thus evident that the predominant growth directions and displacement directly oppose each other. This phenomenon is responsible for the anterior and inferior projection of the jaw which is a consequence of displacement that occurs during the growth which proceeds largely in a superior and posterior direction. Thus, the mandible becomes projected forward, notwithstanding the fact that actual forward growth at the chin itself is relatively slight. Mandibular elongation involves additions of bone at each condyle (endochondral bone formation) and along the posterior border of the ramus (bone remodeling). This results in a linear mode of growth somewhat comparable to that found in typical long bones. The overall enlargement of the mandible, however, is accompanied by a complex series of major regional bony remodeling changes that serve to adapt each individual area to a total pattern of growth (Enlow,1968). The process of relocation of a former portion of the mandible into a part of the new anatomical region is the key factor that underlines the basis for continued remodeling as the mandible increases in size. Metal implant studies have shown that structural changes occur in the mandible in both forward and backward mandibular growth rotations (Björk, 1969; Björk and Skieller, 1983). These intricate mandibular growth processes occur simultaneously with growth activity in the maxilla, the cranial base and facial soft tissue. These changes are progressive and sequential, and they repeat themselves continuously until growth terminates (Enlow,1968).

The growth curve of the mandible, shown against the background of Scammon's curves (Scammon, 1930), follows general body growth more closely than does the maxilla. A pubertal acceleration in general body growth affects the jaws and parallels a dramatic increase in sexual development. Males reach puberty on average two chronological years (Broadbent, Broadbent and Golden, 1975) or one and a half chronological years (Lewis, Roche and Wagner, 1982) later than females. Skeletal maturity indicators (SMI) show that the male mandibles attain a maximum growth spurt one SMI later than do those of females (Fishman, 1982). It is generally believed that growth ceases in the late teens (Riolo et al., 1974; Greulich and Pyle, 1976; Moyers et al., 1976). Behrents (1984) in a treatise on the continuum of growth, showed that in the aging craniofacial skeleton a variety of morphological changes occur beyond this age. Late mandibular growth changes may thus affect an orthodontically treated dentition.

Variation in mandibular morphology and size contributes more significantly to most malocclusions than does maxillary variability (McNamara, 1983). The mandible is for example more apt to be at fault in both Class I and Class III malocclusions than is the maxilla. When there are significant variations in mandibular morphology, both the upper and lower dentitions have to adapt during development (Moyers, 1988).

When bones such as the maxilla and mandible are "abnormal" in shape, size or position, it is usually due to changes in the composite of local morphogenic and functional conditions. The bones themselves may actually have developed normally were it not for these conditions. If a bone is altered as a result of clinical intervention, but the functional environment that produced it is not, subsequent growth will continue to comply with the unchanged environment and "relapse" may follow (Enlow, 1986).

5.3 Dimensional changes of the mandible during growth

In order to understand how orthodontics affects facial growth it is important to study facial growth which takes place in the absence of orthodontic treatment. Male and female parameters are presented in Tables X, XI, XII, XIII, XIV and XV. The differences between the sexes are well illustrated (Adapted from Riolo, Moyers, McNamara and Hunter, 1974). These differences can be compared to those of this study (Table XVI).

TABLE X

AGE RELATED MEAN VALUES OF CERTAIN MANDIBULAR ANTEROPOSTERIOR SPATIAL POSITIONAL CHANGES FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Sella-Nasion-Point B (SNB):

Male Age(X)	N	Degrees(X)	S.D.	Female Age(X)	N	Degrees(X)	S.D.
10	45	76.5	2.5	10	35	76.6	3.5
12	44	77.3	2.7	12	27	77.7	3.4
14	40	77.3	3.1	14	25	77.9	3.8
16	23	78.2	3.9	16	9	79.2	2.3

Sella-Nasion-Pogonion (FACPLANE):

Male Age(X)	N	Degrees(X)	S.D.	Female Age(X)	N	Degrees(X)	S.D.
10	45	76.9	2.4	10	35	77.2	3.5
12	44	77.9	2.6	12	27	78.4	3.4
14	40	78.2	3.0	14	25	78.8	4.1
16	23	79.3	3.5	16	9	80.2	2.5

Frankfurt Plane/Nasion-Pogonion (FAC-ANGL):

Male Age(X)	N	Degrees(X)	S.D.	Female Age(X)	N	Degrees(X)	S.D.
10	24	82.1	3.4	10	14	84.0	3.5
12	24	82.6	3.8	12	14	85.0	3.0
14	20	83.3	3.7	14	9	86.7	3.7
16	13	82.5	3.9	16	5	86.0	2.5

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE XI

AGE RELATED CHANGES IN MANDIBULAR GROWTH DIRECTION - ANGULAR AND LINEAR VALUES FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Male / Female

Sella-Nasion/Gonion-Gnathion (GOGN-SN):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
10	45	34.4	4.5	10	35	35.0	4.8
12	44	33.5	4.8	12	27	34.0	5.1
14	40	32.9	5.0	14	25	33.5	6.0
16	23	32.6	5.2	16	9	31.1	3.1

Franfurt Plane/Mandibular Plane (FMA):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
10	24	29.6	5.0	10	14	28.9	4.2
12	24	29.4	5.5	12	13	28.1	5.2
14	20	27.7	5.8	14	9	24.8	5.8
16	13	28.7	5.2	16	5	25.8	3.0

Condylar Plane/Nasion-B Point (FAC-AXIS):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
10	45	83.6	3.4	10	35	84.3	3.1
12	44	84.5	3.3	12	27	84.8	3.0
14	40	84.9	3.5	14	25	84.5	3.3
16	23	84.7	3.7	16	9	87.7	3.1

Nasion-Menton (ANTFACH-MM):

Age(X)	N	mm(X)	S.D.	Age(X)	N	mm(X)	S.D.
10	45	118.7	5.7	10	35	115.1	6.7
12	44	123.3	6.3	12	27	118.3	6.0
14	39	130.3	7.9	14	25	122.3	5.9
16	23	136.8	7.9	16	9	123.2	5.1

Sella-Menton (POSFACH-MM):

Age(X)	N	mm(X)	S.D.	Age(X)	N	mm(X)	S.D.
10	45	73.6	4.6	10	35	70.2	4.1
12	44	77.6	5.3	12	27	73.7	5.1
14	40	82.9	5.6	14	25	76.6	5.5
16	23	88.2	5.9	16	9	79.1	4.3

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE XII

AGE RELATED MEAN VALUES OF MANDIBULAR GONIAL ANGLE GROWTH CHANGES FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Menton-Gonial Intersection Articulare Posterior (GONANGLE):

Male Age(X)	N	Degrees(X)	S.D.	Female Age(X)	N	Degrees(X)	S.D.
10	46	128.0	4.9	10	35	127.5	4.5
12	44	126.5	5.2	12	27	126.2	4.2
14	39	124.0	5.3	14	25	125.0	4.7
16	23	123.5	5.9	16	9	122.2	4.2

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE XIII

AGE RELATED MEAN VALUES OF MANDIBULAR CORPUS LENGTH GROWTH CHANGES FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Gonion-Gnathion (GOGN-MM):

Male Age(X)	N	mm(X)	S.D.	Female Age(X)	N	mm(X)	S.D.
10	46	74.4	2.8	10	35	73.4	4.4
12	44	77.9	3.2	12	27	75.9	4.1
14	40	82.4	3.8	14	25	78.9	4.0
16	23	86.3	3.6	16	9	81.0	4.0

Gonion-Menton (CORL-MM):

Male Age(X)	N	mm(X)	S.D.	Female Age(X)	N	mm(X)	S.D.
10	46	69.6	3.0	10	35	69.0	4.2
12	44	73.1	3.5	12	27	71.5	4.0
14	39	77.4	3.9	14	25	74.8	4.[illegible]
16	23	80.9	3.6	16	9	77.6	[illegible]

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE XIV

AGE RELATED MEAN VALUES OF MANDIBULAR RAMUS HEIGHT CHANGES FOR MALES AND FEMALES (Population sample from Riolo et al., 1974)

Male / Female

Gonion-Condylion (GOCO-MM):

Age(X)	N	mm(X)	S.D.	Age(X)	N	mm(X)	S.D.
10	46	54.0	3.5	10	35	51.5	2.7
12	44	57.2	3.9	12	27	54.6	3.9
14	40	61.6	4.4	14	25	56.8	3.5
16	23	66.1	4.1	16	9	60.5	2.4

Articulare-Gonion (RAMH-MM):

Age(X)	N	mm(X)	S.D.	Age(X)	N	mm(X)	S.D.
10	46	44.2	3.4	10	35	41.6	3.2
12	44	46.7	3.8	12	27	44.9	3.9
14	40	49.8	4.6	14	25	46.4	4.6
16	23	54.3	4.1	16	9	49.6	3.9

X = Mean
N = Sample size
S.D. = Standard deviation

TABLE XV

AGE RELATED MEAN VALUES OF MANDIBULAR CHIN BUTTON/TAPER CHANGE (Population sample from Riolo et al., 1974)

Male / Female

Nasion-Pogonion/Mandibular Plane (FAC-PLANE):

Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
10	45	68.3	3.8	10	35	67.5	3.0
12	44	68.2	3.7	12	27	67.5	2.9
14	39	68.6	3.4	14	25	67.5	2.6
16	23	67.8	3.7	16	9	68.6	2.3

X = Mean
N = Sample size
S.D. = Standard deviation

5.4 Objectives

There exists no longitudinal growth data for the mandibular dimensions as defined for this or another similar sample (Table I). There is also no data in respect to orthodontic treatment available to enable one to compare the changes occurring in the mandibles of this sample during orthodontic treatment, as well as changes occurring following orthodontic treatment, to other studies noted previously.

Hence, the purpose of this chapter was to:

i) study some longitudinal mandibular changes which occur during and following orthodontic treatment and

ii) study the relationships of the observed mandibular changes to post-treatment lower incisor irregularity.

5.5 Materials and methods

The basic description of the materials used and the methods employed to assess the data are documented in Chapter 3 of this thesis.

For this part of the study the only metrical parameter measured on the study models, for comparison with the cephalometric mandibular dimensions, was the Little Irregularity Index (Little, 1975).

The cephalometric measurements used were obtained with the use of the Oliceph computer programme and included the following:

1. The mandibular antero-posterior position (degrees):
   i) SNB (Sella-Nasion-Point B) (Steiner, 1953).
   ii) SND (Sella-Nasion-Point D) (Steiner, 1953).
   iii) FACPLANE (Sella-Nasion-Pogonion) (Björk/Jarabak: Jarabak and Fizzell, 1972).
   iv) FAC-ANGL (Facial angle: FH/Nasion-Pogonion) (Ricketts, 1981).
2. Mandibular growth direction:
   a) Angular values:
      i) GOGN-SN (Sella-Nasion/Gonion-Gnathion) (Steiner, 1953).
      ii) FMA (Frankfurt mandibular plane angle) (Tweed, 1954).
      iii) FAC-AXIS (Facial-axis angle) (Ricketts, 1981).
      iv) MAND-ARC (Mandibular arc) (Ricketts, 1981).
      v) L-FACH (Lower facial height) (Ricketts, 1981)
   b) Linear values (millimetres):
      i) ANTFACH-MM (Nasion-Menton, Anterior facial height) (Björk/Jarabak: Jarabak and Fizzell, 1972).
      ii) POSFACH-MM (Sella-Gonion, Posterior facial height) (Björk/Jarabak: Jarabak and Fizzell, 1972).
      iii) SGO-NME (Anterior to posterior facial height ratio) (Björk/Jarabak: Jarabak and Fizzell, 1972).
3. Mandibular growth rotation (degrees) as described by Björk/Jarabak (Jarabak and Fizzell, 1972):
   i) ART ANGLE (Articular angle: S-Ar-Go).

ii) GON ANGLE (Gonion angle: Ar-Go-Me).

iii) SUMANGLE (Aggregate of N-S-Ar, S-Ar-Go, Ar-Go-Gn).

4. Gonial angle dimension (degrees) as described by Björk/Jarabak (Jarabak and Fizzell, 1972):

i) GONSLING (Gonial sling: Ar-Go-N).

ii) CORSLING (Corpus sling: N-Go-Me).

iii) GONANGLE (Summation of above: Ar-Go-Me).

5. Corpus length dimension (millimetres) as described by Björk/Jarabak (Jarabak and Fizzell, 1972):

i) GOGN-MM (Gonion-Gnathion).

ii) CORL-MM (Gonion-Menton).

6. Ramus height dimension (millimetres) as described by Björk/Jarabak (Jarabak and Fizzell, 1972):

i) GOCO-MM (Gonion-Condylion).

ii) RAMH-MM (Articulare-Gonion).

7. Chin button size/taper (degrees) as described by Ricketts et al. (1979):

FAC-TAPE (Facial Taper/N-Gn'-Go')

8. Corpus dimension ratio to cranial base as described by Björk/Jarabak (Jarabak and Fizzell, 1972):

CORLCRAN (Go-Me/SN)

9. Mandibular length relationships (millimetres) as described by Oliceph (1987):

i) GOGNGC (GOGN minus GOCO)

ii) GOGN-GOCO (mandibular length from Condylion to Gnathion)

5.6 Results

The results are set out in Tables XVI and XVII.

TABLE XVI

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT TO THE MANDIBLE
(Friedman test included)

VARIABLE	T1 MEAN	T1 S.D.	T2 MEAN	T2 S.D.	T3 MEAN	T3 S.D.	p-value	T1-T2 Pairwise	T1-T3 Differences	T2-T3
SNB	76.81	3.34	76.49	3.43	77.37	3.68	0.0006	x	x	–
SND	73.72	3.18	73.99	3.35	75.32	3.62	0.0001	x	–	–
FACPLANE	77.52	3.37	77.76	3.56	79.05	3.83	0.0001	X	–	–
FAC-ANGL	88.37	3.00	88.90	3.41	89.99	3.58	0.0001	x	–	–
GOGN-SN	33.44	4.93	34.05	5.76	32.19	6.24	0.0001	x	+	+
FMA	23.09	4.69	23.39	5.52	21.46	7.11	0.0001	x	+	+
FAC-AXIS	88.94	4.11	88.36	4.46	89.43	5.13	0.0001	+	x	–
MAND-ARC	29.91	5.47	30.76	5.95	33.90	5.91	0.0001	x	–	–
L-FACH	43.56	4.44	44.62	4.83	44.03	5.01	0.0001	–	x	+
ANTFACH-MM	115.91	5.94	122.65	7.34	126.49	7.90	0.0001	–	–	–
POSTFACH-MM	74.44	4.89	78.89	6.27	85.01	7.98	0.0001	–	–	–
SGO-NME	64.32	4.39	64.50	4.93	67.25	5.17	0.0001	x	–	–
ARTANGLE	146.11	7.11	146.08	7.43	146.10	7.62	0.58	x	x	x
GONANGLE	124.31	6.34	124.44	6.54	121.83	6.81	0.0001	x	+	+
SUMANGLE	393.89	5.38	394.46	5.98	391.78	6.36	0.0001	x	+	+

GONSLING	52.03	4.26	51.02	4.52	49.63	4.28	0.0001	x	+	+
CORSLING	72.27	4.56	73.42	4.76	72.20	5.30	0.0001	-	x	+
GOGN-MM	72.84	4.37	76.04	4.71	78.68	5.39	0.0001	-	-	-
CORL-MM	70.97	4.29	74.08	4.47	76.72	5.79	0.0001	-	-	-
GOCO-MM	56.26	3.91	59.83	4.57	63.66	8.65	0.0001	-	-	-
RAMH-MM	42.94	4.16	46.12	5.25	51.49	6.82	0.0001	-	-	-
FAC-TAPE	68.57	4.06	67.78	4.26	69.18	4.59	0.0013	x	x	-
CORLCRAN	1.00	0.13	1.00	0.06	1.01	0.06	0.0006	-	-	x
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	-

S.D. = Standard deviation

Friedman test:

+ = Statistically significant, $p < 0.05$ (TI > T2, T3)

\- = Statistically significant, $p < 0.05$ (TI < T2, T3)

x = Statistically not significant, $p > 0.05$

TABLE XVII

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE MANDIBULAR DIMENSIONS TO THE LOWER INCISOR IRREGULARITY (L-IRREG)

L-IRREG

	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
SNB	-0.23	0.03	-0.24	0.02	-0.25	0.01
SND	-0.23	0.03	-0.21	0.05	-0.27	0.01
FACPLANE	-0.17	0.12	-0.17	0.11	-0.22	0.04
FAC-ANGL	-0.15	0.16	-0.22	0.04	-0.27	0.01
GOGN-SN	0.04	0.73	0.04	0.74	0.008	0.94
FMA	0.01	0.89	0.08	0.46	0.02	0.89
FAC-AXIS	-0.09	0.39	-0.07	0.50	-0.10	0.35
MAND-ARC	-0.05	0.66	-0.16	0.14	0.05	0.63
L-FACH	0.13	0.23	0.06	0.59	0.10	0.34
ANTFACH-MM	0.001	0.99	-0.02	0.84	0.17	0.12
POSTFACH-MM	-0.03	0.81	-0.07	0.53	0.02	0.87
SGO-NME	-0.04	0.74	-0.05	0.62	-0.06	0.60
ARTANGLE	-0.02	0.82	-0.04	0.69	0.01	0.91
GONANGLE	0.04	0.73	0.08	0.46	0.04	0.71
SUMANGLE	0.06	0.61	0.05	0.63	0.06	0.59
GONSLING	0.07	0.52	0.07	0.54	-0.01	0.95
CORSLING	0.01	0.90	0.00	0.99	0.01	0.94
GOGN-MM	-0.09	0.40	-0.05	0.63	0.03	0.75
CORL-MM	-0.12	0.27	-0.07	0.54	0.11	0.30
GOCO-MM	0.04	0.70	-0.06	0.57	0.19	0.07
RAMH-MM	-0.07	0.54	-0.18	0.09	-0.01	0.89
FAC-TAPE	0.06	0.59	0.06	0.59	0.09	0.43
CORLCRAN	-0.23	0.04	-0.15	0.15	-0.07	0.54

r = Spearman Correlation Coefficient
p = Probability value, significance level 0.05

The purpose of the measurements in this part of the study was to assess the longitudinal changes in the size and spatial position of the mandible. The observed changes were subsequently correlated with the Little Irregularity Index (Little, 1975).

Changes noted during the treatment period (T1-T2) varied depending on whether they were influenced by the orthodontic treatment or were mostly due to growth. The variables changing significantly were the FAC-AXIS, L-FACHL, ANTFACH-MM, POSTFACH-MM, CORSLING, GOGN-MM, CORL-MM, GOCO-MM, RAMH-MM, CORLCRAN and L-IRREG (Table XVI).

Practically all the mandibular dimensions changed significantly ($p < 0.05$) from the end of treatment to the final observation (T2-T3). The exceptions ($p > 0.05$) were the articular angle (ARTANGLE) and the ratio comparing the corpus length to anterior cranial base (CORLCRAN) (Table XVI).

The r-values were all small (Table XVII). However, certain variables did show significant correlations ($p < 0.05$). The clinically significant correlations were those correlating the changes occurring during the post-orthodontic period (T2-T3). The treatment period (T1-T2) represented the active orthodontic phase and although a Little Irregularity Index mean value of 0.43 was attained at the end of treatment (T2), indicating well aligned mandibular anterior teeth, the final observation (T3) value is the real indicator of success (Table XVI). The end of the post-orthodontic period (T3) was measured a mean of approximately 7 years post-treatment.

5.7 Discussion

The mandible, the most highly mobile of the craniofacial bones, is singularly important, for it is involved in the vital functions of mastication, maintenance of the airway, speech and facial expression. The modes, mechanisms and sites of mandibular growth are complicated and much argued in the literature (Moyers, 1988).

The growth movements of the mandible (Tables X, XI, XII and XIII), in general, are complemented by corresponding changes occurring in the maxilla (Chapter 4). As the maxilla becomes displaced anteriorly and inferiorly, a simultaneous displacement of the mandible in equivalent directions and approximate extent occurs. The mandible does, however, lag behind the growth of the maxilla and reaches its growth spurt approximately one and a half chronological years later (Lewis, Roche and Wagner, 1982). The mandible also continues to change deep into adulthood (Behrents, 1984).

For the purpose of a better understanding of the effect of mandibular change, as well as the accompanying treatment effects on the long-term stability of the post-orthodontic dentition, it was deemed essential to discuss the mandible as a separate entity.

The mandibular anteroposterior position changes to a more prognathic situation during growth. This was indicated by the norms in Tables X and XI, and amply supported by the values in Table XVI. The SNB, SND (Steiner, 1953), FACPLANE (Björk, 1969) and the FAC-ANGL (Ricketts, 1981; Holdaway, 1983) did not show any significant change during treatment (T1-T2). Significant changes were, however, measured during the post-orthodontic period (T2-T3). All four variables, at both the end of active orthodontic treatment (T2) and at the final observation (T3), were within the accepted norms found in the literature. These changes were all growth related and were expected (Riolo et al., 1974). Moreover, all these changes can influence the stability of the dentition. The Spearman correlation coefficients were small, but did correlate significantly ($p < 0.05$) with the Little Irregularity Index (Little, 1975) (Table XVII). This finding supports similar data reported by Richardson (1986) and Perera (1987).

Mandibular growth direction and growth rotation gives an indication of the forwards and/or downwards displacement of the chin in space (Björk, 1969; Ricketts, 1981; Björk and Skieller, 1983). The mandibular plane angle decreases with growth (Table XI) (Riolo et al., 1974). This is supported by the measurements recorded in this study. The GOGN-SN (Steiner, 1953), FMA (Tweed, 1962, 1966) and MAND-ARC (Ricketts, 1981) all changed significantly ($p = 0.0001$) during the period studied (T1-T3) (Table XVI). The GONANGLE and SUMANGLE (Björk, 1969) also changed significantly ($p = 0.0001$) indicating a closing rotation of the mandible from the start of the orthodontic treatment to the final observation (T1-T3). The FAC-AXIS and L-FACH (Ricketts, 1981) did not change meaningfully with growth (Table XI). Any change thus occurring here must be ascribed to treatment mechanics. The angles did, however, remain practically unchanged throughout the period studied (T1-T3) ($p > 0.05$), indicating sound orthodontic technique. King (1960, 1974) reported that insufficient vertical control during orthodontic treatment could lead to lower incisor crowding. The significant change, although not clinically important, of these two dimensions ($p = 0.0001$) occurred as a closing rotation during the post-orthodontic period (T2-T3). No significant correlation could, however, be shown between the Little Irregularity Index and these variables (Table XVII). The Björk/Jarabak cephalometric analysis (Oliceph, 1987) measured the posterior to anterior face height ratio. The values of ANTFACH-MM, POSTFACH-MM and SGO-NME portrayed in Table XVI showed a continued increase from the start of treatment to the final observation (T1-T3) ($p = 0.0001$). Similar measurements are recorded during normal growth (Table XI). The SGO-NME (67.25%) measured at the final observation (T3) is a larger value compared to the suggested norm (60-64%). This supports the forward closing rotation of the mandible. The GONANGLE representing the summation of the GONSLING and CORSLING also decreased below the norm (121.83 < 123-137 degrees) which is an indication of a closing rotation, but no significant correlation could be shown with lower incisor irregularity (Table XVII). The fact that the mandible rotated clockwise during treatment prevented the bite from opening, an occurance which played a significant role in preventing the lower incisor crowding side-effects noted by King (1960, 1974).

It is generally accepted that the mandible rotates clockwise or anti-clockwise during growth (Tables XI and XII). This occurs especially during the pubertal growth spurt (Schudy, 1965). These rotations have also been demonstrated by Björk (1969) and Björk and Skieller (1983). The lower incisor is functionally related to the upper incisor, a fact that is illustrated by the small changes occurring in the interincisor angle during the growth rotation of the mandible. The rotation also has an anteriorly displacing effect on the maxillary teeth (Björk, 1969; Björk and Skieller, 1983). The closing rotation of the mandible can affect the overbite-overjet situation and subsequently lead to relapse with resultant incisor irregularity.

Mandibular dimensional changes occurred throughout the period studied (T1-T3). Continued increase of the corpus length (GOGN-MM, CORLH-MM) and ramus height (GOCO-MM, RAMH-MM) is shown in Table XVI. These increases also occur during normal growth (Table XIII). These mandibular changes occurred simultaneously with the abovementioned variables and could thus in combination affect the dentition. No significant correlation between lower incisor crowding and these four variables could be determined (Table XVII). Other variables, however, also give an indication of mandibular anterior displacement, being SNB, SND, FACPLANE and FAC-ANGL. These show significant correlations as shown in Table XVII.

Although numerous authors (Haavikko and Bäckman, 1973; Shapiro, 1974; Little, Wallen and Riedel, 1981; Rönnerman and Larsson, 1981; Little, 1990) reported mandibular incisor crowding following orthodontic treatment, they did not record the variables in this format. Associations between lower incisor crowding and certain mandibular dimensions were reported in the literature (Richardson, 1986; Behrents et al., 1989). The forward growth of the mandible during the post-orthodontic period (T2-T3) as noted previously and also described by Behrents (1984) thus appears to influence the late lower incisor crowding. This phenomenon is illustrated by the small, but significant correlations between the Little Irregularity Index at the post-orthodontic assessment (T3), and the SNB, SND, FACPLANE and FAC-ANGL variables which indicate forward mandibular growth (Table XVII). These are the only significant correlations at T3.

5.8 Conclusions

1. Growth of the mandible occurs within the norms quoted in the literature.
2. In this study orthodontic treatment complimented the growth. No adverse effects such as mechanical opening of the bite which could lead to relapse of treated dentitions took place.
3. Forward and closing rotation of the mandibular growth arc took place.

4. All variables from T1 to T3 corresponded with published norms.

5. The closing and forward displacement of the mandible post-treatment, could be mostly responsible for the increase in the irregularity of the lower incisors.

CHAPTER 6

A LONGITUDINAL EVALUATION OF THE ANTEROPOSTERIOR RELATIONSHIP OF THE MAXILLA TO THE MANDIBLE IN ORTHODONTICALLY TREATED SUBJECTS

6.1 Introduction

The first texts that systematically described orthodontics appeared after 1850 and in this respect Norman Kingsley's Oral Deformities is a most notable example (Proffit, 1986). Despite the contributions of Kingsley and his contemporaries the emphasis in orthodontics remained on the alignment of teeth and the correction of some facial proportions. The functioning occlusion did not attract great attention, and it was common practice to remove teeth to correct tooth alignment. This philosophy was severily critisized in later years (Angle, 1907).

Edward H. Angle (1907), the "father of modern orthodonics", can be credited with much of the development of a concept of occlusion in the natural dentition. This work subsequently led to the development of the Angle classification of malocclusion (Angle, 1899, 1906, 1907) which represented an important step in the growing field of orthodontics. This classification provided the first clear description of a normal natural occlusion and subdivided the major types of malocclusion. The classification described three classes of malocclusion based on the occlusal relationships of the first molars. Although mention is usually only made of these three classes, the Angle classification actually provides for four major divisions of occlusion: normal, Class I, Class II and Class III occlusions. Case (1922), Simon (1924), and others (Moyers, 1988) have taken issue with Angle's classification based on a molar relationship, but its usefullness as a ready descriptor of malocclusion has outlasted most critics (Ackerman and Proffit, 1969; Magazini, 1974).

Numerous other concepts in respect of the ideal occlusion have subsequently been published (Bolton, 1958, 1962; Andrews, 1972, 1976; Ricketts et al., 1979; Roth, 1981). It has, however, become clear that even an excellent occlusion is unsatisfactory if it is achieved at the expense of proper facial proportions (Holdaway, 1983, 1984).

The introduction of cephalometric radiography in orthodontics (Broadbent, 1931; Hofrath, 1931) has enabled orthodontists not only to measure the changes of tooth and jaw positions, but also to study facial growth and to evaluate their treatment results. The study of cephalometric radiographs soon made it clear that many Angle Class I, Class II and Class III malocclusions were due to faulty jaw relationships and not just to malposed teeth (Proffit, 1986). Cephalometrics showed how jaw growth could be affected by both functional jaw orthopaedic appliances as well as extraoral traction appliances which are commonly used to control and modify facial form.

Malocclusion is the result of an interaction between jaw position and dental compensation or adaptation. It is possible to have a normal occlusion in spite of an underlying jaw discrepancy or vice versa. A variety of cephalometric analyses are available for case evaluation (Downs, 1948; Steiner, 1953; Tweed, 1954; Ricketts, 1981; Holdaway, 1983; McNamara, 1983).

Although the Angle classification of malocclusion has been used for nearly a century, it refers primarily to those occlusal characteristics which are manifested in the anteroposterior or sagittal plane of space. At the same time it does not distinguish between the skeletal and dental components of a malocclusion. It is of great importance to to be able to distinguish between the various components of a malocclusion when subjects with disharmonies are being evaluated. An important facet of any cephalometric analysis is its ability to evaluate the anteroposterior maxillo-mandibular relationship in a malocclusion. This dimension can be measured, amongst others, by the ANB angle (Steiner, 1953), the Wits analysis (Jacobson, 1975), the anteroposterior dysplasia indicator (APDI) (Kim and Vietas, 1978), the linear measurement of the distance between points A and B projected onto the Frankfurt horizontal plane (AF-BF distance) (Chang, 1987) or the A point convexity (Ricketts, 1981). These analyses while probably being sufficient for analysis purposes could be augmented by similar information provided by the McNamara Nasion vertical (McNamara, 1983), as well as the AO-BO difference measurements (McIver, 1973). High correlations were shown by Oktay (1991) amongst the ANB angle, "Wits" appraisal, AF-BF measurement and the APDI indicator. No one cephalometric analysis will evaluate the entire dento-facial environment completely and it is thus essential to combine measurements to obtain all the relevant information to study an orthodontic problem. Investigations indicate that the ANB angle (Steiner, 1953) is influenced by the locations of Sella and Nasion, the mandibular plane angle and the rotation of the jaws relative to the anterior cranial base. The "Wits" analysis may be used to exclude, to some degree, these facial disharmonies (Jacobson, 1975).

Other parameters are also available to assess the longitudinal anteroposterior changes. They are the arch length, overjet and incisor positions.

Arch length decreases with age (Brown and Daugaard-Jensen, 1951; Moyers et al., 1976) and this decrease could cause the lower incisors to crowd (Lundström, 1969; Carmen, 1978; Perera, 1987).

One of the most common procedures in orthodontics is to correct an excessive overjet. Overjet, after being orthodontically corrected, tends to return to its original value irrespective of whether extraction or nonextraction treatment was performed (Amott, 1962; Bishara, Chadha and Potter, 1973; Bresonis and Grewe, 1974; Little, Wallen and Riedel, 1981; Uhde, Sadowsky and BeGole, 1983; Hellekant, Lagerstrom and Gleerup, 1989).

Lower incisor position is important and should be placed one millimetre ahead of the APO line (Williams, 1985). If the lower incisor root apices are all in the same bucco-lingual plane, if interproximal flat surfaces are created by enamel stripping and if the canines are placed correctly (Williams, 1985), then no lower retainer is necessary post-treatment. Upper incisor stability may be enhanced by keeping its angular relationship to within five degrees to the Rickett's facial axis (Engel et al., 1980). What constitutes an ideal incisor position has been the subject of ongoing debate. It was proposed by Tweed (1941), Margolis (1943) and Speidel and Stoner (1944) that ideally the lower incisor long axis should form an angle of near to 90 degrees to the lower mandibular border. Tweed (1953, 1954) also suggests the use of the Tweed triangle including the FMA, IMPA and FMIA angles, for determining the correct incisor position. A method which directly relates the lower incisor to the chin point is suggested in the Holdaway ratio which requires that the distance between the lower incisal edge and the NB line be equal to the distance between hard tissue pogonion and the NB line (Steiner, 1953). Lower incisors must be in a definite relationship to the soft tissue in order to produce facial aesthetics and this should be taken into consideration when planning treatment (Lindquist, 1958). Various cephalometric incisor position guidelines have been documented in the literature (Downs, 1948; Steiner, 1953; Tweed, 1954; Ricketts, 1981).

In spite of certain weaknesses, cephalometric measurements do enable orthodontists to obtain more consistant and stable results.

The goals of modern orthodontics are largely to create the best possible occlusion, facial aesthetics and occlusal stability. Harmony between anteroposterior occlusal relationships, jaw position and jaw growth ultimately determines the quality of the orthodontic result achieved (King, 1974; Uhde, Sadowsky and BeGole, 1983; Sandusky, 1983; Little, 1990). Riedel (1950) recommended the use of the SNA, SNB and ANB angles to measure anteroposterior relationships. The ANB angle is recognized as a sagittal discrepancy indicator and is widely used in cephalometric analyses (Riedel, 1950; Steiner, 1953; Brown, 1981; Freeman, 1981; Hussels and Nanda, 1984; Jarvinen, 1986). Little (1990), however, could not show any correlation between his Irregularity Index and various dento-facial parameters in the post-orthodontic period. Moreover the complexity of the post-orthodontic situation makes it seem that retention needed to be more or less permanent (Parker, 1989). This pessimistic picture makes it imperative to further research in this regard, especially when different samples can be used and the results compared to those that have already been described and published in the literature.

Anteroposterior dimensional changes which occur during normal growth affects orthodontic results and it is therefore imperative for orthodontists to take cognizance of normal growth during orthodontic treatment.

6.2 Dimensional changes of variables during normal growth

Anteroposterior dimensional growth changes have been well described in the literature (Riolo et al., 1974, 1979; Moyers et al., 1976). An indication of how the ANB angle changes during normal growth is set out in Table XVIII (Adapted from Riolo et al., 1974).

Certain measurements which may affect the anteroposterior facial morphology have been described in the preceeding and succeeding chapters of this thesis. The maxillary changes (SNA and A-CONVEX) (Chapter 4), the mandibular changes (SNB) (Chapter 5), overjet (OJB), arch length (ARCHL and LITTLE-A) (Chapter 7) and the lower incisor (I-NB-MM, I-NB-DEG and I-APO-MM), upper incisor (I-NA-MM, I-NA-DEG and I-FACAX) and interincisal angle (I-I) (Chapter 8).

6.3 Objectives

There exists no longitudinal growth data for the anteroposterior dentofacial dimensions as defined for this or another similar sample (Table I). There is also no data available to enable one to compare the changes occurring in these dimensions during orthodontic treatment, as well as changes occurring following orthodontic treatment, to other studies noted previously.

Hence, the purpose of this part of the study was to:

i) assess the longitudinal changes in certain

TABLE XVIII

AGE RELATED MEAN VALUES OF CHANGES OF THE ANB ANGLE FOR MALES AND FEMALES
(Population sample from Riolo et al., 1974)

Male				Female			
Age(X)	N	Degrees(X)	S.D.	Age(X)	N	Degrees(X)	S.D.
6	37	5.3	2.2	6	25	4.7	2.2
10	45	4.3	2.0	10	35	4.0	2.7
13	43	3.7	2.0	13	29	3.5	2.4
16	23	3.2	2.3	16	9	2.6	2.4

X = Mean
N = Sample size
S.D. = Standard deviation

anteroposterior dentofacial dimensions in orthodontic subjects.

ii) determine possible relationships between growth, changes induced by orthodontic treatment and post-treatment lower incisor crowding.

6.4 Materials and methods

The basic description of the materials used and the methods employed to assess the data have been documented in Chapter 3 of this thesis.

Cephalometric measurements were obtained with the use of the Oliceph computer program included the following:

1. The maxillary position as described by:
   i) the Sella-Nasion A point angle (SNA) (Steiner, 1953).
   ii) the convexity of A point (A-CONVEX) (Ricketts, 1981).
2. The mandibular position as described by:
   i) the Sella-Nasion-Point B angle (SNB) (Steiner, 1953).
3. The maxillo-mandibular anteroposterior relationship as described by:
   i) the Point A-Nasion-Point B angle (ANB) (Steiner, 1953).
   ii) the Point A and Point B discrepancy relative to the functional occlusal plane expressed as the Wits analysis (WITS-MM) (Jacobson, 1975).
4. The upper incisor position as described by:
   i) the upper incisor position measured to the Nasion-Point A line in millimetres (I-NA-MM) and

degrees (I-NA-DEG) (Steiner, 1953).

ii) the upper incisor position measured to the facial axis of Ricketts (1981) (I-FACAX) (Engel et al., 1980).

5. The lower incisor position as described by:

i) the lower incisor position measured to the Point B-Nasion line in millimetres and degrees (I-NB-MM and I-NB-DEG) (Steiner, 1953).

ii) the lower incisor position measured to the Point A-Pogonion line in millimeters (Ricketts, 1981).

6. The interincisor angular relationship (I-I) as described by Steiner (1953).

The orthodontic study casts were measured with digital calipers capable of measuring to 0,01mm. The following variables were measured:

1. An indication of lower incisor crowding in millimetres - the Little Irregularity Index (L-IRREG) (Little, 1975).

2. Arch length dimension measured in millimetres, being the aggregate of the left and right measurement taken from the mesial aspect of the mandibular first molar to the interproximal contact of the central incisors (LITTLE-A) (Little, Riedel and Engst, 1990).

3. The arch length (ARCHL) measured in millimetres as the perpendicular measurement from the mandibular mesial bimolar line to the interproximal contact point of the lower central incisors (Moyers et al., 1976).

4. The overjet (OJB) measured in millimetres as the upper to lower incisor anteroposterior overlap (Moyers, 1988).

The data were subjected to descriptive statistics such as mean and standard deviation for each of the three evaluations. The Friedman test was used to test for significant differences during the active treatment period (T1-T2), during the post-orthodontic period (T2-T3) and in general throughout the study (T1-T3). The Wilcoxon and the Chi-square tests tested for significant differences amongst the variables at the three time intervals. The Spearman correlation coefficient and the Kruskal-Wallis tests were used to test the relationships of the different variables with the degree of lower incisor irregularity (Little, 1975) at the final observation (T3) (Zar, 1984). The significance level of this part of the study was set at 0.05.

6.5 Results

The longitudinal changes which were assessed in respect to the anteroposterior relationship between the maxilla and the mandible are recorded in Tables XIX and XX. These changes were subsequently correlated with the Little Irregularity Index (Little, 1975) (Tables XXI and XXII).

Although the mean SNA value was significantly reduced during the active orthodontic treatment (T1-T2) and a similar trend was shown throughout the observation period (T1-T3), it remained reasonably stable after removal of the appliances (T2-T3). The mean SNB value did not change significantly during the treatment period (T1-T2), but a significant increase was measured after active treatment (T2-T3). The metrical characters ANB and A-CONVEX were significantly

TABLE XIX

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT TO THE ANTEROPOSTERIOR RELATIONSHIP OF THE MAXILLA TO THE MANDIBLE
(Friedman test included)

	T1		T2		T3			T1-T2	T1-T3	T2-T3
ARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	p-value	Pairwise	Differences	
IA	81.31	3.56	79.55	3.50	80.07	3.53	0.0001	+	+	x
IB	76.81	3.34	76.49	3.43	77.37	3.68	0.001	x	x	−
IB	4.50	2.39	3.05	2.01	2.70	2.28	0.0001	+	+	+
-CONVEX	4.16	2.95	1.98	2.71	1.12	2.99	0.0001	+	+	+
ITS-MM	1.19	3.93	0.46	3.05	0.81	3.64	0.23	x	x	x
-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	−
IB	6.21	3.29	2.85	0.85	3.17	1.23	0.0001	+	+	X
RCHL	23.50	2.37	20.75	3.19	20.01	3.52	0.0001	+	+	+
ITTLE-A	61.06	4.31	56.69	6.83	54.99	7.05	0.0001	x	+	+
-NA-DEG	22.99	9.09	22.60	8.44	22.35	7.48	0.83	x	x	x
-NA-MM	4.14	2.86	2.84	2.61	3.49	2.60	0.002	+	x	−
-NB-DEG	27.22	6.41	28.43	5.08	26.71	4.72	0.03	x	x	+
-NB-MM	3.89	2.11	4.32	1.63	4.04	1.65	0.15	x	x	x
-I	126.40	11.05	127.05	9.34	129.38	7.79	0.03	x	−	x
-APO-MM	0.42	2.86	1.29	1.90	0.86	1.93	0.03	−	x	x
/-FACAX	4.02	8.65	5.57	7.29	6.19	6.08	0.19	x	x	x

.D. = Standard deviation
= Significant, $p < 0.05$ (TI > T2, T3)
= Significant, $p < 0.05$ (TI < T2, T3)
= Not significant, $p > 0.05$

TABLE XX

FREQUENCY OF THE SEVERITY OF MOLAR AND CANINE ANTEROPOSTERIOR CUSP RELATIONSHIPS RECORDED PRE-TREATMENT, POST-TREATMENT AND POST-RETENTION

VARIABLE	T1	T2	T3
	N	N	N
MOLAR L			
0	43 (48.9%)	83 (94.3%)	80 (90.9%)
2	21 (23.9%)	3 (3.4%)	5 (5.7%)
3	24 (27.3%)	2 (2.3%)	3 (3.4%)
MOLAR R			
0	37 (42.0%)	82 (93.2%)	82 (93.2%)
2	25 (28.4%)	4 (4.5%)	3 (3.4%)
3	26 (29.5%)	2 (2.3%)	3 (3.4%)
CANINE L			
0	17 (19.3%)	83 (94.3%)	80 (90.9%)
2	43 (48.9%)	4 (4.5%)	6 (6.8%)
3	28 (31.8%)	1 (1.1%)	2 (2.3%)
CANINE R			
0	18 (20.5%)	82 (93.2%)	80 (90.9%)
2	45 (51.1%)	6 (6.8%)	7 (8.0%)
3	25 (28.4%)	0	1 (1.1%)

N = Sample size
0 = Normal molar and canine relationship (Table II)
2 = Full cusp (edge-edge) deviation (Table II)
3 = More than a full cusp deviation (Table II)
Percentage representation in parentheses

TABLE XXI

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE IRREGULARITY OF THE MANDIBULAR INCISORS AT T3 TO THE VARIABLES DEPICTING ANTEROPOSTERIOR DIMENSION AT T1, T2 AND T3

	LITTLE IRREGULARITY INDEX					
	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
SNA	-0.13	0.22	-0.15	0.16	-0.23	0.03
SNB	-0.23	0.03	-0.24	0.02	-0.25	0.02
ANB	0.15	0.17	0.09	0.39	0.03	0.79
A-CONVEX	0.04	0.72	0.04	0.75	-0.02	0.84
WITS-MM	0.07	0.49	0.09	0.42	0.01	0.89
OJB	0.20	0.06	0.09	0.43	0.04	0.75
ARCHL	-0.12	0.27	0.04	0.72	0.01	0.89
LITTLE-A	-0.11	0.32	0.06	0.55	-0.01	0.94
I-NA-DEG	-0.01	0.96	0.07	0.53	0.09	0.42
I-NA-MM	0.04	0.74	0.08	0.45	0.08	0.46
I-NB-DEG	-0.16	0.14	-0.08	0.43	-0.06	0.59
I-NB-MM	-0.07	0.50	0.13	0.23	0.03	0.75
I-I	0.06	0.61	-0.02	0.85	-0.09	0.39
I-APO-MM	-0.19	0.06	-0.03	0.80	-0.07	0.51
I/-FACAX	-0.03	0.81	-0.04	0.67	-0.09	0.39

r = Spearman correlation coefficient
p = Significance level, $p < 0.05$

TABLE XXII

KRUSKAL-WALLIS TEST INDICATING WHETHER SIGNIFICANT RELATIONSHIPS EXISTED BETWEEN MOLAR AND CANINE ANTEROPOSTERIOR RELATIONSHIPS AT T1,T2 AND T3 AND THE IRREGULARITY OF THE LOWER INCISORS AT T3

	LITTLE IRREGULARITY INDEX		
	T1	T2	T3
VARIABLE	p	p	p
MOLAR L	0.34	0.55	0.45
MOLAR R	0.05	0.61	0.34
CANINE L	0.13	0.88	0.13
CANINE R	0.13	0.88	0.13

p = Probability level for significance, $p < 0.05$

reduced during the period T1 to T3. The WITS-MM measurement also showed a reduction throughout the study (T1-T3), but this was not a significant reduction (Table XIX).

Overall the incisor positions measured to NA, NB, APO and the facial axis were not significantly ($p > 0.05$) altered during the period studied (T1-T3), but the angular relationship between the incisors (I-I) did increase significantly. The mean millimetre measurement of the upper incisor to the NA line as well as the millimetre value to the APO line changed significantly ($p < 0.05$) during treatment (T1-T2). The upper incisor moved anteriorly without changing its angulation and the lower incisor uprighted significantly (I-NB-DEG) post-orthodontically (T2-T3). The mean overjet (OJB) having been significantly reduced during treatment (T1-T2), showed a non-significant increase after appliance removal (T2-T3). The mean arch length (ARCHL and LITTLE-A) showed a significant decrease throughout the study (T1-T3) (Table XIX).

The lower incisor irregularity (L-IRREG) decreased significantly during treatment (T1-T2) and increased significantly following active treatment (T2-T3) (Table XIX).

Practically all the Class I, II and III molar and canine relationships, with minor exceptions, were treated to a Class I relationship (T1-T2). The new positions remained stable during the post-orthodontic period (T2-T3) (Table XX).

Significant, but weak correlations were shown for the SNA and SNB angular changes compared to the degree of lower incisor irregularity at the final observation (T3). The SNB angle, however, showed significantly weak correlations throughout the study with the Little Irregularity Index (Little, 1975) (Table XXI).

No significant Spearman correlations (Table XXI) or Kruskal-Wallis test relationships (Table XXII) could be shown between the other variables measured and the Little Irregularity Index (Little, 1975).

6.6 Discussion

Successful growth modification during treatment is possible only in subjects who have a significant amount of growth remaining (Proffit, 1986; King, Keeling, Hocevar and Wheeler, 1990). Attempts at growth modification should begin with girls at eight to nine years and boys at ten to eleven years of age (King et al., 1990). Although jaw growth continues after puberty, the magnitude is rarely enough to allow for correction of significant skeletal jaw discrepancies. If point A is distalized in a nine year old and Nasion and Pogonion continue to grow normally then the profile convexity will decrease in an anteroposterior dimension. After thirteen years of age the convexity reduction in girls at point A is minimal (Ricketts et al., 1979; Ricketts, 1981) making it difficult to reduce the profile convexity because Nasion and Pogonion are not growing forward as much as in the earlier years (King et al., 1990). This parameter shows similar decreases in both sexes up to fifteen years of age (4.5mm to 1.7mm), but thereafter it only decreases in males (1.7mm to -0.4mm) (Ricketts, 1981). The ANB angle normally reduces during growth (Table XVIII), but can also be reduced by a variety of orthodontic treatment modalities which affect point A and point B (Gianelly and Valentini, 1976; Ricketts et al., 1979). The relatively small, but significant reduction of SNA throughout the study (T1-T3) could possibly be attributed to the relatively high starting mean age of 11.92 years (Table I and XIX). The mandible in contrast to the maxilla showed significant growth, borne out by the increase in the SNB angle, in the post-orthodontic period (T2-T3) (Table XIX).

Changes in the apical bases during treatment have been shown to be greatly dependent on growth. Holdaway in 1956 noted that the greatest change which occurs in the reduction of the ANB angle is due to a reduction of the SNA angle which results after the inhibiting of maxillary alveolar growth as well as a remodelling in the region of point A following retraction of the upper incisors. This observation was borne out in the present study (Table XIX). The upper incisor was significantly retracted during treatment (I-NA-MM 4.14mm to 2.84mm), which probably resulted in the significant reduction of the SNA angle, which is in contrast to the SNB angle which showed no significant change in this period (T1-T2). In most subjects with favourable mandibular growth who were evaluated by Holdaway (1956) the angle, SNB increased only slightly, or exhibited no change. The latter finding could be due, either to a bite opening, or to a lingual movement of the lower incisors. Either of these factors could alter the relationship of point B to the body of the mandible.

Mean reductions in the parameters ANB, A-CONVEX and WITS-MM reductions during the period T1 to T2 were thus mainly due to treatment. Upper incisor retraction appeared to play a major role in the posterior movement of point A and subsequently in the reduction of the angle SNA. This reduction in the angle SNA appeared to influence the reduction of the angle ANB as non-significant mandibular growth and lower incisor proclination during treatment (T1-T2) could not have influenced point B significantly, hence the relatively unchanged SNB value at the post-treatment evaluation (T2). The mean ANB angle, A-CONVEX and WITS-MM were all reduced following active treatment (T2-T3), indicating that following orthodontic treatment, growth caused the further reduction. It has been reported that growth continues well into adulthood (Behrents, 1984) and the present study appears to support this theory as the post-treatment mean age was 21.47 years (Table I). Thus, with the forward displacement of the mandibular symphysis as a result of growth, the lower incisors would be pushed forward relative to the upper incisors (Perera, 1987). The mean interincisal angle increased throughout the study (T1-T3) (Table XIX) which tends to support the above observation. It may be postulated that the upper incisor moved anteriorly and that the lower incisor uprighted posteriorly because of this forward movement of the mandible resulting in a slight, but non-significant increase in the overjet during the post-orthodontic period (T2-T3) (Table XIX). Although the overjet increased during T2-T3, it is still within clinically acceptable norms (Moyers et al., 1976) and it is a significant improvement in respect to the initial measurement. The increase showed a slight return towards the original value which supports the data presented by other authors (Amott, 1962; Bishara, Chadha and Potter, 1973; Bresonis and Grewe, 1974; Little, Wallen and Riedel, 1981; Uhde, Sadowsky and BeGole, 1983). During this latter period the incisor positions remained within accepted clinical norms (Steiner, 1953; Engel et al., 1980; Ricketts, 1981). The lower incisor movement which results from forward mandibular growth, is resisted by the occlusion of the upper teeth, which may result in an increased crowding of the mandibular incisors (Perera, 1987). In the present study, the Little Irregularity Index (Little, 1975) measured an increase following the removal of the orthodontic appliances (T2-T3) (Table XIX). The maxillary incisors showed a slight anterior movement following treatment which could be the result of this phenomenon. The overall non-significant changes of the individual positions of the upper and lower incisors during the period studied show the tendency of the teeth to return towards their original positions.

Physiologic drift is defined as the natural migration of teeth, with no applied force, into spaces created by extractions, congenital absence of teeth, dental decay, proximal attrition, or orthodontic tooth movement (Creekmore, 1975). The term mesial drift is not new in dental literature and means that the buccal teeth of a dentition move in a mesial direction. It is said to be present, in a normal dentition and to result from a natural physiological force which becomes effective as soon as the first permanent molars erupt into occlusion (Downs, 1938). Downs (1938) described four factors which could lead to a reduction in dental arch length:

i) constitutional factors affecting the growth of the maxilla and mandible.

ii) an anterior component of force.

iii) a restraining or distal force emanating from the labial and buccal musculature.

iv) a lack of resistance to these two latter opposite forces induced by the disturbance of the proximal contact points of the teeth.

The significant reduction of the mean arch length measured in the present study (Table XIX) is thus in accordance with clinical observations made in previous publications (Downs, 1938; Brown and Daugaard-Jensen, 1951; Creekmore, 1975; Moyers et al, 1976). These reports were not as elaborately supported with statistics. Lundström (1969), Carmen (1978) and Perera (1987) reported that the decrease in arch length could cause lower incisor crowding. The post-treatment (T2) and post-orthodontic (T3) lower incisor crowding of the present study is within clinically acceptable norms according to Little (1975) (Table XIX). Although it is possible that the significant decrease in the arch length could have contributed to the increase in the Little Irregularity Index during the post-orthodontic interval, no significant correlation could be shown between these variables (Table XXI).

The attainment and maintenance of a Class I molar relationship is commonly identified as being a prime goal of orthodontic treatment (Strang, 1943; Graber, 1966; Thurow, 1966; Tweed, 1966; Begg, 1971, 1977; Moyers, 1988). A Class I molar relationship has also been identified as being the pre-eminent key to a normal occlusion (Andrews, 1972, 1976). Molar malrelationships are rarely self-correcting (Arya, Savara and Thomas, 1973), and it may be expected that they will become more severe with time if left untreated (Harris and Behrents, 1988).

In this study the indications are that the Class I molar and canine relationships are indeed most stable. There were 176 molar and canine relationships treated and of those 94.3% (left) and 93.2% (right) were changed to Class I molar and 94.3% (right) and 90.9% (left) were changed to Class I canine relationships. The majority of these remained stable in their corrected positions, 90.9% (left molar), 93.2% (right molar), 93.2% (right canine) and 90.9% (right canine) (Table XX). It was reported that none of 69 untreated patients starting in a Class I cusp-in-groove relationship moved out of that relationship (Harris and Behrents, 1988). In contrast Harris and Behrents (1988) also believe that for some unexplained reason Class II molar relationships appeared to be intrinsically more stable in natural untreated occlusions. Angle's (1907) original reason that the maxillary first molar is invariably in the correct anteroposterior position when in a Class I relationship, appears to be no longer tenable.

According to the Little Irregularity Index (Little, 1975), incisor positions as well as molar and canine relationships, the malocclusions in this study were successfully treated. The post-orthodontic results were clinically acceptable and stable (Tables XIX and XX). The slight, but significant increase in the crowding of the lower incisors during the post-orthodontic period (T2-T3) (L-IRREG 0.43 to 1.71mm) is well within the acceptable limits (Little, 1975).

Although changes occurred in the anteroposterior dimensions which possibly contributed to the small increase in the L-IRREG during the post-orthodontic period, only weak significant correlations could be shown for the angular measurements SNA and SNB at the final observation (T3) when compared to the Little Irregularity Index (L-IRREG) at T3. The other variables measured showed no significant correlations when compared to L-IRREG at this assessment (Tables XXI and XXII).

A successfully treated dentition may show small irregularities following orthodontic treatment and patients and parents should be informed of this possibility at the initial appointment.

6.7 Conclusions

1. The anteroposterior dimensions (ANB and A-CONVEX) decreased from T1 to T3, mainly due to a combination of treatment effect on point A and growth effect on point B. This was noted in the decrease of the angle SNA (T1-T2), and as an increase in the angle SNB, following the active orthodontic treatment (T2-T3).
2. The mandible continued its growth during the post-pubertal period.
3. Continued decrease in the variables ANB and A-CONVEX throughout the study (T1-T3) could affect lower incisor irregularity, but no significant correlations were shown between the Little Irregularity Index and these variables.
4. Molar and canine relationships once established in Class I remained extremely stable and no significant interdependence could be shown between these and lower incisor crowding.
5. Weak, significant correlations were shown between the angular change in the angle SNB at T1 to T3 and the lower incisor crowding at the final observation (T3), but a similar observation was noted for the angle SNA only at the final observation.
6. The measurement of the arch length decreased significantly throughout the study. Although this change from T1 to T2 was treatment related, growth and mesially displacing occlusal forces could also be held partly responsible for the post-treatment changes.
7. Post-treatment lower incisor irregularity appears to be growth related.

CHAPTER 7

A LONGITUDINAL EVALUATION OF POST-ORTHODONTIC OCCLUSAL CHANGES AND THEIR RELATIONSHIPS TO LOWER INCISOR CROWDING

7.1 Introduction

7.1.1 Development of the occlusion

Orthodontists should have an in-depth understanding of prenatal dental development which includes normal and abnormal development of the teeth within the jaws (Moyers, 1988). Tooth development takes place over a relatively long period of time. It begins in the seventh week of embryonic life (primary dentition), and continues well into the late teenage years (third molar of the secondary dentition) (Moss-Salentijn and Hendricks-Klyvert, 1985).

Embryonic development of both the mandibular and maxillary dentitions proceeds through four stages. These are: initiation of odotogenesis, bud stage, cap stage and bell stage (Longmore and McRae, 1985; Moss-Salentijn and Hendricks-Klyvert, 1985; Moyers, 1988). The twenty deciduous tooth buds differentiate through the cap and bell stages at rates that manifest recognizable sequence patterns, or polymorphisms (Burdi et al., 1970). These variations in embryonic sequence may be the prenatal antecedents of the polymorphisms of sequence which may be observed in postnatal dentitions (Garn and Burdi, 1971). According to Moyers (1988) examples of sequential polymorphism are:

i) the mandibular incisors which tend to precede their maxillary counterparts in eruption.

ii) teeth closely positioned show stronger correlations in crown size than those more widely spaced.

iii) the presence of sexual dimorphism in the calcification and eruption of permanent teeth with the exception of the third molars.

Throughout their development the tooth germs move, relative to each other and relative to the developing bone of the jaw. Once most of the crown has been formed and all crown odontoblasts have differentiated, eruptive movements begin. Nolla (1960), incorporating the previously noted four stages, described ten stages of tooth development. Permanent teeth do not begin to erupt until after their crowns are complete (Nolla stage 6). Eruption may be described as a predominantly vertical movement of teeth from their sites of development inside the jaws, until their crowns eventually establish a functional occlusion (Moss-Salentijn and Hendricks-Klyvelt, 1985).

Various theories which attempt to explain dental eruption have been proposed, studied and debated (Melcher and Beertsen, 1977). These include theories such as root growth, pulp growth, tissue fluid pressure, bone growth and the periodontal fibres creating a pulling force on the erupting tooth (Longmore and McRae, 1985; DuBrul, 1988).

Alveolar bone is formed during the development, and especially during the eruption, of the teeth. Alveolar bone, which comprises the sockets in which the roots of the teeth are suspended, is part of the bone of the jaws. There is no sharp line of division, and one can only designate bone arbitrarily as being part of the alveolar or basal bone of the jaws. This division is in fact based on clinical experience. When an individual becomes edentulous his alveolar bone is gradually lost or, in an anodontic subject, is never formed. Only basal bone remains when the teeth are absent and it is thus clear that alveolar bone is entirely dependent on the presence of teeth for its existence. Alveolar bone allows for movement of teeth, whether this movement is due to active eruption, mesial drifting or remodelling as part of orthodontic tooth movement. The correct positioning of the teeth during orthodontic movement is imperative as this will influence the morphology of the interdental septae and shape of the alveolar crests, parameters frequently used as indicators of periodontal health (Moss-Salentijn and Hendricks-Klyvert, 1985).

The secondary dentition is made up of 16 upper and 16 lower teeth. All teeth are longest mesiodistally near their occlusal thirds while they tend to be broadest buccolingually near their cervical thirds. The mesiodistal dimension ensures a continuous line of interdental contact, establishing the unity of the dental arch. At the same time, the narrowing of the teeth in the cervical region provides space for the interproximal alveolar bone and gingival soft tissues. The buccolingual bulging of the dental crown near its cervical third provides a sheltering overhang that protects both the thin crests of alveolar bone and its covering gingivae which fit tightly around the necks of the teeth (DuBrul, 1988).

The establishment of certain occlusal relationships have been described by Baume (1950) and Friel (1927, 1954). They related the establishment of a Class I occlusion (Angle, 1899, 1907) to the mesial movement of teeth and the forward growth of the mandible. Diet can play a significant role in this regard. A diet which includes coarse, rough food such as is consumed by the Eskimos and North American Indians for example, would tend to eliminate cuspal interferences and thus permit an easier forward movement of the mandible. An edge to edge incisor relationship can easily result in ethnic groups which manifest severe dental attrition. Begg (1977) based his treatment philosophy on the severe dental attrition which may be found in the Australian Aborigines.

The concept of "normal occlusion" which implies variations around an average or mean value, is fundamental to orthodontic diagnosis (Moyers, 1988). Any deviation from this "normal occlusion" which is a hypothetical concept or goal, has traditionally been termed a malocclusion (Moyers, 1988). Ideal occlusion rarely exists in nature, and is therefore sometimes termed the imaginary "normal" (Proffit, 1986). As there is no universally acceptable definition of "ideal occlusion", diagnosis in orthodontics is based on a concept of the ideal. Occlusion can be defined as "the normal fit of the teeth when they are brought together" (The Shorter Oxford English Dictionary, 1975). Articulation is therefore a function of feeding during which opposing dental arches are ultimately brought into contact by rhythmic cycles that prepare food for swallowing. A fundamental understanding of all aspects of occlusion is necessary to achieve orthodontic treatment goals which include optimal facial aesthetics acceptable to the subject's social environment, optimal dental aesthetics, optimal functional occlusion, optimal oral health and stability of treated results.

7.1.2 Characteristics of a static occlusion

Andrews (1972) described "six keys to normal occlusion" as a measure of the static occlusal relationship which may be used to evaluate the success of orthodontic treatment. The keys included evaluation of the molar relationship, crown angulation (mesiodistal tip) and inclination (labiolingual or buccolingual "torque"), rotations, tight interproximal contacts and a normal Curve of Spee. These qualities were considered meaningful as they were all present in each of 120 non-orthodontic normals, and the lack of even one of the six keys was a defect predictive of an incomplete end result in treated subjects. Most orthodontists accept Andrew's static tooth alignment as the primary objective in the orthodontically treated dentition. A further of this "normal occlusion" is that the teeth reach maximum intercuspation with the condyles in centric relation position (Andrews, 1972; Aubrey, 1978).

The relationship of the mesiobuccal cusp of the upper first molar to the buccal groove of the lower first molar (Angle, 1899, 1907), irrespective of its shortcomings, is used to classify dentitions in everyday orthodontic practice (Chapter V). Ricketts et al. (1979) provided a check list of requirements to which an ideally treated dentition should conform. Amongst these requirements are the occlusion of the upper second premolar with the mesial marginal ridge of the lower first molar as an indication of a Class I occlusion, and the correct mesiobuccal rotation of the maxillary first molar which allows for the alignment of the distobuccal and mesiolingual cusp with the distal third of the respective opposite maxillary canine. Ricketts (1969) also suggested that the lower first molar should be rotated in a mesiobuccal manner which would allow its distobuccal cusp to contact the middle of the mesial marginal ridge of the lower second molar.

7.1.3 Functional occlusion

Functional occlusion refers to a state of the occlusion in which:

i) the occlusal surfaces are free of interferences to allow for smooth gliding movements of the mandible,

ii) there is freedom for the mandible to close or to be guided into maximum intercuspation in centric occlusion, and

iii) occlusal contact relations contribute to occlusal stability (Ash and Ramfjord, 1982).

The movement of the mandible is dictated by the condyles, via the articular discs, against the slopes of the glenoid fossae and the articular eminences. Any conflict between condylar positions and tooth positions may induce pathological responses in the neuromuscular system surrounding the temporomandibular joint (Aubrey, 1978).

In order to achieve a functional occlusion, centric occlusion and centric relation should coincide. Teeth should function according to a mutually protected scheme with no interferences which could cause the mandible to detour excessively in order to prevent damage to teeth (Roth, 1981). Centric relation should be the starting point for all treatment decisions (Aubrey, 1978). Procedures to record centric relation and to transfer measurements to articulators were discussed by Chiappone (1975, 1977). The manipulation technique described by Aubrey (1978) or any other which is compatible with the neuromuscular system, should be carried out at each orthodontic visit. When initial contact is reached, manipulation stops and the subject's true occlusal relationship, centric relation occlusion, is observed.

All jaw movements take place within certain boundaries which can be traced as envelopes of movement in the sagittal and horizontal planes (Posselt, 1952).

7.1.4 Concepts of functional occlusion

Three major concepts of occlusion have been described in the literature; bilateral balanced occlusion (Von Spee, 1890), unilateral balanced occlusion (group function) (Mann and Pankey, 1960; Schuyler, 1935) and mutually protected occlusion or canine disclusion (D'Amico, 1958; Williamson, 1976; Roth, 1981). Bilateral balanced occlusions, although acceptable for complete dentures, are not easily accepted by natural dentitions (Celenza and Nasedkin, 1978). Unilateral balanced occlusion was introduced for application in periodontics and restorative dentistry. The importance of canine function or mutually protected occlusion only gained popularity from the 1950's. The mutually protected occlusion is considered the ideal not only for the natural untreated dentition (D'Amico, 1958), but also for the post-orthodontic occlusions (Roth, 1981).

While the anterior teeth are important for good occlusal integrity (McHorris, 1979), the canines can be considered nature's stress breakers as canine contact in lateral excursion causes an immediate break in the tension of temporal and masseter muscles. Canines have a higher minimal lateral threshold than do the other teeth. There are indications that canine-protected (mutually) occlusions have significantly less periodontal trauma than the other funtional groups. To achieve anterior disclusion all the anterior teeth must be established in positions resistant to change. Harmony between condylar disclusion and anterior disclusion results in effortless, physiologic mandibular movements (McHorris, 1979). Bell and Harris (1983) suggested that the angulation of the articular eminence may be used as a guide for the orthodontic placement of the maxillary incisor teeth. Various ideal positions have been described for the anterior teeth (Downs, 1948; Steiner, 1953; Tweed, 1966; Moyers et al., 1976; Ricketts, 1981).

The posterior teeth must stop closure of the mandible when in function and thus prevent hard contact of the anterior teeth. McHorris (1979) described the various interocclusal contacts and advocated elimination of the anterior component of force by proper organization of these posterior interocclusal contacts.

7.1.5 Requisites for an ideal functional occlusion at the end of orthodontic treatment as a precaution against temporomandibular disorders

The occlusal parameters essential for functional occlusion may be described as follows (Dawson, 1974):

i) stable centric contact points on all teeth which evenly distribute the stress of occlusion. Less attrition will occur and the centric contact points prevent over-eruption of teeth.

ii) anterior guidance which harmonises with the functional border movements.

iii) disclusion of posterior teeth should occur in protrusive movements.

iv) disclusion on the balancing side should occur during lateral mandibular movements.

v) no posterior interferences should be present on the working side.

Three areas constantly creating occlusal interference are: a hanging palatal cusp especially of the upper second molar, the oblique ridge and hanging palatal cusp of an upper first molar, and the mesiobuccal incline of the lingual cusps of premolars (Dawson, 1974).

A stable jaw relationship should have slight freedom in centric occlusion, i.e. the mandible should not slide when closing in centric position, but should be able to move from centric relation (CR) to centric occlusion (CO) (less than 1mm) (Timm, Herremans and Ash, 1976). Gnathologic assessment of post-treatment orthodontic subjects produced controversial findings. Orthodontists are often criticized for failing to achieve a stable centric relation occlusion (CO=CR). Equilibration is suggested as part of the post-treatment detailing (Timm, Herremans and Ash, 1976), but care must be taken against indiscriminate equilibration where ideal orthodontic detail was not achieved during treatment (Roth, 1981). Roth (1981) noted that equilibration should not be performed until growth is completed. Research results are confusing as untreated control groups show CO-CR differences (Sadowsky and BeGole, 1980; Sadowsky and Polson, 1984) and pre-treatment CO=CR differences returned after active orthodontic treatment (Johnston, 1988). Studies in favour of orthodontic treatment are those of Rinchuse and Sassouni (1983) which showed no differences in the number, location or severity of balancing or protrusive contacts between the occlusions of subjects following orthodontic treatment and those subjects who had no orthodontic treatment, but with ideal static occlusion. No association between extraction treatment and posterior condylar position was found following treatment (Gianelly, 1989).

In the 1980's, articles in various journals suggested that orthodontic treatment might play a role in initiating temporomandibular disorders. Litigation was the order of the day. On the other hand, it was also claimed that orthodontic treatment might be effective in alleviating the signs and symptoms of temporomandibular disorders, but it is apparent from the abovementioned that orthodontists should not expect temporomandibular symptoms to disappear during treatment (Machen, 1989). All the controversy surrounding the occlusion and temporomandibular disorders resulted in the initiation of a research program by the American Association of Orthodontists to determine the risks and responsibilities involved in orthodontic treatment. The scientific evidence from this research program enabled Behrents and White (1992) to make the following conclusions:

i) consistently significant associations between the structure (dental and osseous) and temporomandibular disorders do not exist,

ii) the development of temporomandibular joint disorders cannot be predicted,

iii) no method of temporomandibular joint disorder prevention has been demonstrated,

iv) the prevalence of temporomandibular disorders increases with age; thus temporomandibular joint disorders may originate during orthodontic treatment, but may not be related to the treatment,

v) orthodontic treatment per se does not initiate temporomandibular disorders,

vi) evidence favours the benefits of orthodontic treatment; orthodonitcs, as a part of the regimen of care, may assist in the lessening of the symptoms, and

vii) once temporomandibular disorders are present, its cure cannot be assumed or assured.

According to Alexander (1986) active orthodontic treatment is complete:

i) when there is coincidence of centric relation and centric occlusion.

ii) when a Class I canine relation with normal canine function is present.

iii) if the lower intercanine width is maintained.

iv) when normal inter-incisal angle, overbite, overjet and correct anterior torque are established.

v) when normal posterior overbite and overjet are present.

vi) when there is a levelled curves of Spee in the dental arches.

vii) when all spaces are closed, rotations are eliminated, roots are parallelled near extraction sites and when proper cusp interdigitation is achieved.

As teeth will move after appliance removal. orthodontists must incorporate a certain measure of overcorrection of tooth positions (Roth, 1981). Parameters which may change after treatment include deepening of the curve of Spee, mesial tipping of teeth (teeth distally tipped during treatment will tend to settle better than teeth already mesially inclined), rotation and tipping of teeth into adjacent extraction sites and the fact that maxillary lingual cusps tend to migrate downwards until they find an occlusal stop against opposing teeth.

In order to understand the occlusal changes which occur during orthodontic treatment, orthodontists must have insight into dimensional changes which occur in dental arches during the normal growth of individuals who have not undergone orthodontic treatment.

7.2 Normal growth of the dental arches

7.2.1 Arch width

Arch width growth is almost totally due to alveolar process growth since there is little skeletal width increase at the time of tooth eruption (none in the mandible) (Moyers, 1988). Width changes are significantly different in the maxilla and the mandible. Dental arch width increases correlate strongly with vertical alveolar process growth, the direction of which is different in the upper and in the lower arches (Moyers et al., 1976). The maxillary alveolar processes diverge while the mandibular alveolar processes are more parallel. These morphological features allow for more maxillary increase in width during growth. Maxillary arches can thus be more easily altered during treatment (Moyers, 1988). Dental arch width increases are closely related to the events of dental development (Moyers et al., 1976).

The intercanine width in the mandible increases only slightly as a result of a distal tipping of the primary cuspids into the primate spaces when the secondary incisors erupt. It does not widen significantly thereafter. The maxillary cuspids are placed further distally in the arch than their primary predecessors and erupt pointing mesially and labially allowing for more widening than is possible in the mandible (Moyers, 1988). Intercanine width and its immutability have long been the subject of heated discussions in the orthodontic literature (Angle, 1907; Lundström, 1925; Strang, 1949). Intercanine width was investigated and found to show a rapid increase from six to nine years of age, corresponding with permanent incisor and canine eruption (Barrow and White, 1952; Moorrees, 1959 and Sillman, 1964). From ten to twelve years there is a decrease in intercanine width, which then remaines stable according to Moorrees (1959), but which, according to the other authors continues to decrease. There were small decreases in intercanine width, with the most significant change occurring in females from thirteen to twenty years, but in general this dimension was shown to be very stable in males (Sinclair and Little, 1983). Post-retention studies of treated cases have typically shown marked reductions in intercanine width (Shapiro, 1974; Gardner and Chaconas, 1976; Little, Wallen and Riedel, 1981). In many cases the intercanine widths reduced to below their original dimensions, whereas in a few cases, some nett gain after expansion was noted (Sinclair and Little, 1983).

Maxillary premolar width increases more than does its mandibular counterparts as a result of the growth direction of the alveolar processes noted ealier.

The mandibular first molars erupt with a lingual inclination irrespective of the fact that in this jaw the alveolar process growth is almost vertical. They do not upright until after the eruption of the second molars. This uprighting allows for an increase in bimolar width, but does not signify an increase in the diameter of the mandible itself. Furthermore, both first molars move forward at the time of the late mesial shift to occupy any remaining leeway space and thus assume a narrower diameter along the convergent dental arch (Moyers, 1988). The mandibular intermolar width was shown to increase between the ages of nine to fourteen years in both sexes , but remained constant thereafter (Moorrees, 1959). Intermolar width in general appears to remain very stable with some degree of sexual dimorphism being present (Sinclair and Little, 1983). A distinct difference in intermolar width was noted between nonextraction and extraction therapy groups. The extraction sample showed a decrease in intermolar width during treatment which continued during retention, but the nonextraction sample maintained, and in some cases showed an increase, in intermolar width (Shapiro, 1974). The nonextraction group resembled a sample of untreated subjects from the Burlington Growth Centre at the University of Toronto (Sinclair and Little, 1983).

The only postnatal mechanism for widening the mandibular basal bony width other than orthognathic surgey is bone deposition on the lateral borders of the body of the mandible (Bell, Proffit and White, 1980). All bone growth occurs by surface addition and orthodontic therapy will not stimulate bone growth (Fairbank, 1948). Bone deposition offers little help to clinicians who wish to widen mandibular dental arches (Moyers, 1988). The same observation is not true for the maxilla as a result of differences which occur during alveolar process development. Where a cross-bite is apparent, maxillary expansion may be considered as part of a treatment aiming to co-ordinate the maxillary and mandibular arches (Chaconas, De Alba and Levy, 1977). Maxillary expansion during active growth can be accomplished with rapid midpalatal expansion appliances (Haas, 1980) while orthognathic surgery is possible for this purpose in the adult subjects. A debate has raged since the nineteenth century between those advocating expansion by a rapid method (Goddard, 1893) and those who claimed that expansion should be gained by a slower process, which is said to be physiologically less traumatic and possibly more stable (Ferris, 1914). Few studies have followed patients who were subjected to palatal expansion long-term out of retention, yet Timms and Moss (1971) found histological evidence of bony changes as late as 2 years post- expansion. Herold (1989) found that relapse occured in all patients having had transverse expansion of the maxillary arch irrespective of the type of appliance used.

Measurements of arch width dimensions determined in normal untreated subjects are set out in Tables XXIII and XXIV (Adapted from Moyers et al., 1976).

7.2.2 Arch length or depth

Although often measured and reported for research purposes, this parameter does not have the clinical value of the arch circumference measurement. Changes in arch length or depth offer only coarse reflections of changes in the arch perimeter. Sometimes one-half the arch circumference is referred to as "arch length" (Moyers, 1988). Arch length decreases with age in both sexes, with the greatest decrease occurring between nine and fourteen years of age. This decrease corresponds with the replacement of the deciduous by the permanent dentition. Arch length remains more or less constant after fourteen years of age. These observations were made during a longitudinal study of developing dentitions between the ages of three and eighteen years (Moorrees, 1959). In a later study it was shown that the arch length decrease commenced at age three, after completion of the erution of the primary dentition, with the tendency to decrease in length being greater in the mandible

TABLE XXIII

AGE RELATED MEAN VALUES OF MANDIBULAR INTERCANINE DIMENSION (mm) FOR MALES AND FEMALES (Population sample from Moyers et al., 1976)

	MALE		FEMALE	
AGE	MEAN	S.D.	MEAN	S.D.
10	24.97	1.32	24.70	0.93
12	25.14	1.73	24.81	1.42
14	24.73	1.45	24.39	1.14
16	24.66	1.68	23.90	1.76
18	24.81	1.27	23.08	2.01

S.D. = Standard deviation

TABLE XXIV

AGE RELATED MEAN VALUES OF MAXILLARY BIMOLAR DIMENSION (mm) FOR MALES AND FEMALES (Population sample from Moyers et al., 1976)

	MALE		FEMALE	
AGE	MEAN	S.D.	MEAN	S.D.
10	44.46	2.55	43.52	2.51
12	45.34	2.27	44.54	2.23
14	45.86	2.53	44.32	2.47
16	46.63	2.87	45.01	2.65
18	46.69	2.58	43.94	4.19

S.D. = Standard deviation

TABLE XXV

AGE RELATED MEAN VALUES OF MANDIBULAR ARCH LENGTH CHANGE (mm) MEASURED MESIAL OF THE FIRST MOLARS (Population sample from Moyers et al., 1976)

	MALE		FEMALE	
AGE	MEAN	S.D.	MEAN	S.D.
12	23.75	1.87	23.82	1.38
14	23.93	1.35	22.92	1.89
16	23.42	1.68	21.87	1.68
18	23.02	2.45	21.84	2.37

S.D. = Standard deviation

(Moorrees and Chadha, 1965; Moorrees, Lebret and Kent, 1979). Changes in arch length were determined in subjects during adolescence and early adulthood and found to decrease with age (Brown and Daugaard-Jensen, 1951). A decrease in the incisor-canine circumference which was noted from three to eighteen years was associated with a decrease in arch length rather than a narrowing in arch width (Moorrees, 1959; DeKock, 1972). In another study a constant decrease in arch length was shown from the mixed dentition phase into early adulthood (Sinclair and Little, 1983).

Measurements of arch length changes related to different age groups in normal untreated subjects are set out in Table XXV (Adapted from Moyers et al., 1976).

7.2.3 Arch circumference or perimeter

The arch circumference dimension is important as it provides the space to accommodate the dentition. An observed continual reduction in mandibular arch circumference (Moyers et al., 1976) during the different phases of dental development is the result of:

i) a mesial shift of the first permanent molars into the leeway space,

ii) mesial drifting of the posterior teeth throughout life,

iii) interproximal wear of teeth due to diet and function,

iv) lingual positioning of the incisors as a result of differential mandibular-maxillary growth,

v) the original tipped position of incisors and molars (Moyers, 1988),

vi) interproximal caries and early loss of primary teeth (Northway, 1977).

vii) pressure from the third molars during their eruption (Moyers, 1988).

A negative discrepancy between the sum of the mesiodistal tooth dimensions and the arch circumference is noted as a space shortage which is a common problem in many malocclusion. The Little Irregularity Index is an appropriate indication of lower incisor crowding (Little, 1975).

7.2.4 Incisor crowding/irregularity

Lower incisor crowding appears in 30,6% to 47,0% of the population (Mansbach, 1938; Lieb, 1962). The incidence of incisor crowding as shown in a longitudinal study is virtually zero in the maxilla at age six years, but increases to 24% by the age of fourteen years. The frequency of mandibular incisor crowding is said to increase from 14% at six years to 51% at fourteen years of age (Barrow and White, 1952). Cryer (1966) found an incidence of lower incisor crowding of 62% at fourteen years of age and in 60% of these there was an increase in the severity of incisor crowding after the age of eleven years. The cause of lower incisor crowding is generally ascribed to a discrepancy between mesiodistal tooth width and the size of the available supporting bone (Doris, Bernhard and Kuftinec, 1981; Howe, McNamara and O'Connor, 1983). A cross-sectional study (Foster, Hamilton and Lavelle, 1970) showed a different pattern. They found spacing in the mandible at age three, but by seven years of age there was a 70% incidence of crowding and this value increased to 90% by fourteen years and then decreased somewhat by age twenty-five, with females having more crowding than males despite the greater average size of the male dentition. Moorrees (1959) observed a slightly different pattern, showing considerable crowding in the eight to ten year age group. This phase corresponds to the eruption of the permanent canines. According to Moorrees (1959) the crowding decreases between twelve to fourteen years of age and then increased again from fourteen to eighteen years of age. Björk and Skieller (1972) suggested that incisor position may be correlated to the amount and direction of facial growth. A significant correlation was found between increases in incisor crowding and decreases in arch length with age (Lundström, 1969). Incisor irregularity increases from thirteen to twenty years of age with females exhibiting more incisor irregularity than males at the adult stage (Sinclair and Little, 1983). Lower incisor crowding tends to occur in malocclusions which are primarily dental in nature and in those with atypical skeletal patterns (Miethke and Behm-Menthel, 1988).

There are a number of factors which relate to lower incisor irregularity (Wilson, 1967). An evaluation of the causes of lower incisor irregularity points to the complexity of the factors involved in this important problem. The factors are as follows:

i) a disproportion of tooth to bone size relationships may occur.

ii) irregularity increases with an increase in bite closure.

iii) oversized individual teeth reflect congestion in an anterior direction and may thus cause irregularity.

iv) a reduction of intercuspid width due to a premature loss of the deciduous cuspids, as well as a supra-eruption of the lower cuspids due to a late eruption of the upper cuspids causing lingual deflection of the lower cuspid teeth.

v) a mesial, or lingual, inclination of the upper cuspids which cause the lower cuspids to deflect lingually.

vi) variations in lateral excursion of the mandible may result in a lingual inclination of the lower cuspids.

vii) in full cusp Class II cases the lower cuspids assume an upright position with straight lower incisors because of the greater width permitted by the wider embrasures between the maxillary cuspid and the first bicuspid in the Class II relationship. In contrast, in a half cusp Class II molar relationship the restriction in lower intercanine width when the cuspids are in a cusp to cusp occlusion, causes the lower cuspids to occlude with the heavy cingulae of the upper cuspids and in so doing reduce the lower intercuspid width by several millimetres. A Class I relationship places the cuspid in an upright position because of the occlusion within the embrasures which is similar to the full cusp Class II.

viii) rotations of maxillary central and/or lateral incisors have a restrictive effect upon the lower incisor teeth.

ix) the presence of heavy anatomical ridges on the upper incisor teeth.

x) a deflection of anterior teeth due to a mentalis hyperactivity or certain tongue habits.

xi) the presence of a marginal Class III tendency in a Class I occlusion with the forward mandibular pressure causing a slight condensation of the lower incisors.

xii) a tight restrictive upper lip with the presence of small upper lateral incisors resulting in a constriction of the upper arch in the direction of the normal lower arch.

7.2.5 Dimensional changes during orthodontic treatment

It is far easier to bring about changes in the maxilla than it is in the mandible. An increase in maxillary dental arch width and/or length is relatively simple to accomplish, but difficult, if at all possible, to attain in the mandible. There are a variety of means used to increase arch perimeters in certain malocclusions, including lip bumpers, utility arch wires, functional appliances and headgear wear.

These appliances have limited application in the mandible and success is usually only noted when specific conditions favour the use of an appropriate appliance. Few mandibular arch circumferences can be lengthened permanently and there are no magic appliances for doing so. Success is only secured when alteration of muscle function and/or the positions of teeth within the alveolar process is safely possible (Moyers, 1988).

7.2.5.1 Comparison of untreated to treated subjects

Maturational changes in the permanent dentitions of a sample of untreated individuals (Class I) appeared, in general to be similar in nature, but significantly less in extent, than changes observed in similar parameters examined in a post-retention Angle Class I sample of treated subjects (Little, Wallen and Riedel, 1981). Both samples were examined by the same observer using the same methodology. The treated group underwent first-premolar-extractions at a mean age of thirteen years, followed by routine comprehensive edgewise mechanotherapy and retention (Sinclair and Little, 1983).

7.2.6 Overbite and overjet

These variables undergo significant changes during the development of the occlusion. From the early mixed dentition phase to the completion of the adult dentition the average overbite increases slightly and then tends to decrease again, while the overjet shows a continual decrease (Moyers et al., 1976) (Tables XXVI and XXVII as adapted from Moyers et al., 1976). Overjet and overbite typically increase from nine to thirteen years of age, then decrease from thirteen to twenty years of age, resulting in minimal overall changes. These changes are in contrast to the post-retention results of treated cases which show a tendency towards an increase in overbite (Sinclair and Little, 1983). Overbite is correlated with a number of vertical facial dimensions (e.g., ramus height), whereas overjet usually is a reflection of the anteroposterior skeletal relationship (Fleming, 1961). Overjet is also sensitive to abnormal lip and tongue function (Proffit, 1986).

7.3 Correlation of untreated normal occlusions with other dentofacial and skeletal dimensional variables (Predictability)

Mandibular incisors that are more labially inclined pre-treatment are associated with less long-term crowding (Sanin and Savara, 1973; Gilmore and Little, 1984). While being only a weak predictor (r = 0,45) of long-term crowding, the pre-treatment facial pattern that emerges as having a tendency for greater long-term incisor irregularity is a divergent face with wide, upright incisors (Gilmore and Little, 1984). At post-treatment or over the long-term, subjects that were less retrognathic tend to have less lower incisor irregularity (Norderval, Wisth and Boë, 1975; Gilmore and Little, 1984).

TABLE XXVI

AGE RELATED MEAN VALUES OF OVERBITE CHANGE (mm) FOR MALES AND FEMALES (Population sample from Moyers et al., 1976)

	MALE		FEMALE	
AGE	MEAN	S.D.	MEAN	S.D.
10	3.13	1.79	2.83	1.61
12	3.45	1.73	3.13	1.32
14	3.45	1.71	2.87	1.48
16	2.83	2.02	2.97	1.54
18	3.05	1.55	3.03	1.69

S.D. = Standard deviation

TABLE XXVII

AGE RELATED MEAN VALUES OF OVERJET CHANGE (mm) FOR MALES AND FEMALES (Population sample from Moyers et al., 1976)

	MALE		FEMALE	
AGE	MEAN	S.D.	MEAN	S.D.
10	4.01	1.99	3.24	2.10
12	3.91	1.83	3.27	1.84
14	3.48	1.49	2.97	1.50
16	3.14	1.83	2.97	1.69
18	3.16	1.05	2.45	2.60

S.D. = Standard deviation

A correlation between lower anterior crowding and the growth vector of the mandible was cited by Fisk (1966). He believed that a prediction of arch form, final tooth position, and the available space is possible only if the relationship between the skeletal growth pattern and development of the dentition is known.

Lundström (1975), however, found no correlation amongst arch dimension changes in the developmental stage, changes in the incisor position within the mandible, and direction of mandibular growth.

Many other factors are involved in the phenomenon of incisor crowding. Biologic variability, however, may confound even the most carefully executed study.

The results of a longitudinal study (Leighton and Hunter, 1982) showed that patients with severe mandibular arch crowding mesial to the first molars (>4.0 mm) have steeper mandibular planes, greater ANS-PNS to mandibular plane angles, shorter mandibular bodies, shorter posterior facial heights, less mandibular size increase between the ages of nine and fourteen years, and a more clockwise (downwards and backwards) growth of the mandible. The same conclusion could be drawn from Björk's (1963) implant studies.

Carmen (1978) conducted a serial study of mandibular anterior crowding, and its predictability, in untreated cases at ages twelve and eighteen years. The study concentrated on data obtained from study models and included only limited cephalometric measurements. The study showed that there was no significant relationship between incisor crowding, gender nor the Angle classification. Arch length, canine width and molar width changes were found to be insignificant factors in controlling crowding, but may contribute in small measure to a multifactorial relationship associated with crowding. In the whole sample incisor irregularity tended to increase with time, but nearly a third of the cases showed an actual improvement in incisor alignment. It was concluded thus that no single variable measured at either observation time, or the change in any single variable between observations, correlated significantly with crowding changes. Attempts to find correlations between incisor crowding and other dental and skeletal features have been somewhat limited due to difficulties in quantifying incisor crowding and due to the apparent multifactorial aetiology of malalignment (Sinclair and Little, 1983). Sinclair and Little (1983) found that, when changes in individual dental variables were compared, no associations or predictors were of clinical value in predicting incisor crowding.

7.4 Dentofacial growth and tooth position changes

7.4.1 Incisor positions

With skeletal growth incisors undergo uprighting relative to the facial plane (Subtelny, 1959). Anterior teeth appear to be functionally stable within the facial environment and it was indicated that they did not correlate with jaw rotations (Björk and Skieller, 1972). Incisor angulation, superimposed with the cephalometric tracings on the anterior cranial base, appears to be relatively stable, showing compensations for skeletal changes, which result in the maintenance of acceptable occlusal relationships. These compensating changes are limited to a slight proclination of the mandibular incisors, while the maxillary incisors displayed less compensatory movement. Mandibular incisors show a significant degree of eruption, which correlates closely with the amount of mandibular growth, during the change from the mixed to the adult dentition. Mandibular superimposition of cephalometric radiographs (Björk and Skieller, 1983) indicates that a forward movement of the incisors may be correlated with a mesial movement of the mandibular molars (Sinclair and Little, 1985).

No correlations were found between the parameters reflecting lower incisor position and factors relating to the amount and direction of facial growth (Sinclair and Little, 1985).

7.4.2 <u>Molar positions</u>

The effect of positional changes in jaw relationships on the dentoalveolar structures is considerable. Changes in the molar position seem to be characteristic of the different types of facial rotation. Generally a forward (bite-closing) rotation of the maxilla and the mandible results in a more mesial path of eruption of the molars (Sinclair and Little, 1985).

There appears to be a relationship between the amount and direction of dentofacial growth and changes in occlusal features such as overjet, intercanine width and incisor crowding (Hasund and Sivertsen, 1970; Sanin and Savara, 1973; Lundström, 1975; Nordeval, Wisth and Boë, 1975; Nass, 1981). No significant correlations could be found when comparing maturational occlusal changes with a variety of cephalometric variables (Sinclair and Little, 1983, 1985). This does not imply that such correlations do not exist, but rather, that they were not revealed despite extensive analysis (Sinclair and Little, 1985).

7.5 Longitudinal occlusal stability

The modern concept of a dynamic individual occlusion naturaly includes an interest in the stability of the occlusion before, during and after orthodontic treatment. A stable occlusion is dependent on the resultant of all forces acting on the teeth. Adjustment of tooth position occurs throughout a person's lifetime in response to naturally induced changes of occlusal forces associated with wear, in response to pathologic changes in the support mechanism or muscle tonicity, and following dental procedures such as the placement of restorations. However, within the adaptive capacity of the masticatory system, a balance of force is maintained (Ramfjord and Ash, 1966).

The patterns of forces that act on the teeth are far more complex than usually conceived. Research in this regard has been directed toward magnitude of biting forces (Black, 1895; Adler, 1947; Anderson, 1956), the orthodontic aspects of tooth mechanics (Halderson, Johns and Moyers, 1953; Burstone, Baldwin and Lawless, 1961), equilibrium of teeth relative to their biologic environment (Haack and Weinstein, 1963; Weinstein et al., 1963; Dempster and Duddles, 1964), tooth mobility (Muhlemann, 1960; Parfitt, 1960) and tilting movements (Picton, 1962). Few deductions can be made from these studies that are of direct practical value for the stabilization of teeth by occlusal adjustment or other dental procedures (Ramfjord and Ash, 1966).

7.5.1 Lower incisor relapse

Studies evaluating interproximal enamel reduction also report conflicting findings. Peck and Peck (1972a) combined mesiodistal (MD) and faciolingual (FL) dimensions into an index (MD/FL X 100) and recommended mesiodistal width reduction of incisors to place them in an ideal size range to prevent future crowding. They stated that the maximum faciolingual dimension of the mandibular incisors was often found subgingivally and, therefore, plaster casts could not be used to measure this dimension accurately (Peck and Peck, 1972a; 1980). A very close agreement between the intraoral and study cast faciolingual dimensions of the lower incisors measurements were, however, indicated by Gilmore and Little (1984). Edwards (1970) and Boese (1980) suggested that a combination of reshaping of incisor contacts and an incising of supracrestal gingival fibres be used to prevent post-treatment crowding, especially after the correction of dental rotations. Rye (1983) found 23% rotational relapse in a fiberotomized sample compared with a 39% relapse rate for a nonsurgical group. Little, Riedel and Artun (1988) showed in a study of mandibular incisor stability that 61% of dental rotations which have been corrected do not relapse. Their preliminary results indicate that rotations often relapse in spite of circumferential supracrestal fiberotomy (CSF) procedures and conversely that rotations might not recur even in the absence of CSF. Slight reductions of the mesiodistal dimensions of mandibular incisors to correct incisor irregularies may be a rational clinical procedure, but some evidence (Gilmore and Little, 1984) suggests that there is little reason to reduce incisor widths to establish long-term stability of mandibular incisor alignment. Statistical tests to show relationships between the "irregularity index" (Little, 1975) and the "MD/FL index" (Peck and Peck, 1972a) of the dimensions of the mandibular central and lateral incisors clearly demonstrate that only weak associations exist between these variables (Gilmore and Little, 1984).

Little, Wallen and Riedel (1981) concluded that stability of the anterior mandibular segment (minimum of ten years post-retention) was variable and unpredictable. Success with the maintainance of satisfatory mandibular anterior tooth alignment is less than 30% with nearly 20% of the cases likely to show marked crowding some years after removal of retention appliances.

Studies which have incorporated cephalometric analyses in combination with incisor measurements have not substantially increased the predictability of incisor crowding (Sanin and Savara, 1973; Norderval, Wisth and Boë, 1975; Keene and Engel, 1979). During a cephalometric appraisal of subjects who had undergone first-premolar-extraction treatment Shields, Little and Chapko (1985) found that mandibular alignment was unpredictable; no cephalometric parameters such as maxillary and mandibular incisor proclination, horizontal and vertical growth amounts, mandibular plane angle, etc. were useful in establishing a prognosis for relapse of lower anterior alignment.

Sadowsky and Sakols (1982) and Uhde, Sadowsky and BeGole (1983) presented a more optimistic view of post-retention results. The difference in opinion may be due to differences in the appraisal of the measurement techniques by the two research groups Little, Wallen and Riedel (1981) and Little, Riedel and Artun (1988).

7.5.2 Growth cessation and relapse

Since orthodontists have assumed that once facial growth ceases, dento-occlusal changes (relapse) will be minimal and therefore that continued retention may not be necessary. Little, Riedel and Artun (1988) using the Little Irregularity Index (Little, 1975) shows that changes in the occlusion continue, at varying rates, well beyond the point of growth cessation. They found that one factor was consistently predictable; the continuing decrease in mandibular arch length which occurs with time following the removal of retainers.

7.5.3 Spacing of teeth and relapse

In an assessment of subjects who had been out of retention for a minimum of ten years and who had displayed generalized spacing of their anterior teeth prior to treatment, Little and Riedel (1989) showed a consistent reduction of their arch lengths and intercanine widths into their adult years. The incidence of post-retention clinically unacceptable malalignement was lower for the sample with pre-treatment dental spacing.

7.5.4 Maxillary crossbite correction and relapse

The outcome of treatment with various types of appliances to correct buccal crossbites by maxillary expansion and separation of the maxillary halves are recorded by Mossaz-Joelson and Mossaz (1989). The more physiologic sutural adjustment produced by slow maxillary expansion (SME) appliances result in a more stable increase in maxillary width (Storey, 1973). Palatal expansion is more stable when treatment is initiated at an early age (Skieller, 1964; Melsen, 1972, 1975; Storey, 1973; Mew, 1983), with slow expansion procedures (Skieller, 1964; Storey, 1973; Cotton, 1978; Hicks, 1978; Mew, 1983) and with prolonged retention (Thorne, 1960; Timms, 1976; Haas, 1980). Further, stability decreases with an increase in the width of the expansion (Stockfish, 1969). Long-term studies warn again of the effects of cumulative relapse over extended post-treatment periods (Krebs, 1964; Linder-Aronson and Lindgren, 1979). A tendency towards a decrease in the width of the dental arches, four to five years following rapid maxillary expansion (RME), was reported by Krebs (1964). Krebs (1964) found that with conventional jackscrew appliances, skeletal (sutural) expansion was only equal to half of the palatal expansion achieved by the end of the active RME phase. Only 45% of the width of the palatal expansion achieved with RME was maintained 5 years post-retention (Linder-Aronson and Lindgren, 1979). These findings are in agreement with the observations made by Stockfish (1969) who found a 50% relapse in width in his sample within five years following appliance removal. Hicks (1978) stipulated that only eight weeks of fixed retention was required following this type of expansion and did not recommend removable retainers. Rocke et al. (1980) found less relapses occurred in crossbites treated by executing rapid maxillary expansion.

Mossaz-Joelson and Mossaz (1989) used removable retainers for 12 weeks following palatal expansion. The correction of the crossbite was maintained even though an average relapse (30%) occurred. The slow rate of expansion, 8 mm during three months, compared to 8 to 10 mm during one month for conventional RME could be responsible for the post-expansion stability achieved by Mossaz-Joelson and Mossaz (1989). Their data, however, remain to be confirmed by a long-term study. The studies of Krebs (1964) and Linder-Aronson and

Lingren (1979) show that intercanine expansion relapses to a greater extent than does the intermolar width. This finding was confirmed by a longitudinal study on eight Macaca fascicularis monkeys (Vardimon, Graber and Voss, 1989). They used tantalum implants inserted along the facial sutures and dental markers (0,018" s.s. wire) bonded along the buccal crown surfaces of the upper canines and upper molars in order to be able to make their conclusions. They found that the gain in intermolar width exceeded the gain in intercanine width by the end of the relapse phase. The greater the buccal tip of the canine during expansion, the greater the intercanine width relapse.

The last mentioned authors could not entirely explain why buccal tooth tipping in the molar area, as a result of RME, produced a stable intermolar width expansion. A second factor which seems to determine the stabilty following expansion is the selective activity of the circummaxillary sutures.

Vardimon, Graber and Voss (1989) mention intercuspation and muscular pressure as other causitive factors likely to affect canine vs. molar interarch stability. Unlike molar expansion, canine transverse expansion recieves no antagonistic support from the lower arch. Additionaly, the increase in tension of the circum-oral musculature, as a result of the RME (Graber, 1972), essentially acts on the intercanine width.

A low force slow palatal expansion regimen can be of substantial benefit in young patients with transverse maxillary deficiency. Even with slow expansion a 40% overcorrection in intercanine expansion may be required (Vardimon, Graber and Voss, 1989).

7.5.5 Mandibular arch expansion and relapse

The mandibular intercanine width remaines unchanged or decreases during adolescent growth and can thus not be changed during treatment without a tendency to relapse (Strang, 1949; Magill, 1960; Gardner and chachonas, 1976; Riedel, 1976; Berg, 1983). According to Moorrees(1959) the mandibular intercanine width reaches its maximum with eruption of the permanent canines and then decreases slightly with increasing age. The mandibular intercanine width seems to decrease over a long period of time a finding which may be associated with late crowding, both in treated cases (Haavikko and Backman, 1973; Shapiro, 1974; Little, Wallen and Riedel, 1981; Rönnerman and Larsson, 1981; Glenn, Sinclair and Alexander, 1987) and in untreated cases, where a decrease of 0,7 mm was reported by Sinclair and Little (1983). A decrease of 1,8 mm (treated group) and 1,0 mm (untreated group) were found in a study by Owman, Bjerklin and Kurol (1989). In contrast Richardson (1979) reported no major changes in intercanine width in thirteen to eighteen year old untreated individuals. Little, Wallen and Riedel (1981) reported that more than 60% of an extraction sample showed an increase in mandibular intercanine width of more than 1 mm during treatment. Following treatment, however, 60 out of 65 cases showed an intercanine width decrease. An important finding of the Little, Wallen and Riedel (1981) study was that many cases showed post-retention mandibular intercanine widths which were less than they were at the start of treatment.

The lower cuspid and molar widths should not be expanded because of their tendency to relapse (Rocke et al., 1980). Occasionally a malocclusion presents with extreme incisor crowding and a narrow intercuspid width. In such an instance the cuspids may be tipped distally, into the bicuspid extraction space, which tends to increase the intercuspid width. In general, if either the cuspid and/or the molar width have to be expanded, to accommodate all teeth, the case should be treated by extraction (Rocke et al., 1980).

7.5.6 The relapse of overbite and overjet correction

Studies of the long-term results of overbite correction have reported various degrees, ranging from improvement to complete relapse, of post-treatment change (Berg, 1983). A relapse in overbite and overjet of between 25% and 55% has been reported with the length of the follow-up observation period varying from one to more than ten years (Ludwig, 1967; Simons and Joondeph, 1973; Lagerstrom, 1980).

The position of teeth in relation to their supporting basal bone has long been recognized as an important diagnostic factor in treatment planning (Lundström, 1925; Tweed, 1944). In discussing the stability of overbite correction, the mandibular incisor position plays an important role (Steiner, 1960; Ricketts, 1964; Hasund and Ulstein, 1970). Changes in position of the mandibular incisor position relative to the mandibular symphysis, during growth, were described by Björk and Skieller (1972). They related this change to a growth rotation of the mandible which necessitates a compensatory adaptation in the eruption paths of the teeth. This adaptation was termed the dento-alveolar compensatory mechanism (Solow, 1980) and the concept is used in clinical cephalometrics and treatment planning. By advocating different incisor inclinations for different sagittal jaw relationships, clinical guidelines have been developed to use in cephalometric analysis (Steiner, 1959). As an example; the visualized treatment objective (VTO) (Ricketts et al., 1979), relates the mandibular incisor position to the APo line. By using a cranial base referenced growth axis, the vertical dimension could be adapted during VTO analysis (Ricketts, 1960; Ricketts et al., 1979).

By means of a multiple regression statistical approach an average incisor inclination, corresponding to various combinations of sagittal and vertical jaw relations, was calculated (Hasund and Ulstein, 1970). The importance of vertical jaw relationships as being primary factors in post-treatment overbite and mandibular incisor crowding relapse has been ascribed to late condylar growth which occurs without compensatory posterior vertical dento-alveolar development (Schudy, 1974). The equilibrium which should exist between the activity of the intra- and extraoral muscles is another factor which is of importance in occlusal stability (Strang, 1949; Brodie, 1954). The form, and growth pattern of the mandible are factors which influence the stability of overbite correction (Björk, 1969).

Once incisor contact has been established, a factor which influences overbite depth is the inclinations of the lower incisor axes to the the palatal surfaces of the upper incisor crowns. This relationship is known as the interincisor angle (Ballard, 1948). Popovich (1955) investigated the association between the interincisal angle and overbite depth in class II division 2 subjects and reported a positive correlation of r = 0,73. Similar findings were reported by other authors (Backlund, 1960; Solow, 1966; Ludwig, 1967; Simons and Joondeph, 1973). Ludwig (1967) and Simon and Joondeph (1973) reported significant positive correlations between these parameters prior to treatment (r = 0,52 and 0,45 respectively) but could only determine low or no correlations post-retention. In a study of the stability of deep overbite correction Berg (1983) found that when the interincisor angle was less than 140 degrees after treatment, it became an important factor in the amount of overbite stability achieved. Where incisor contact is not achieved, either because of the size of the overjet or because there is an open bite, these dental factors are less important in determining overbite depth (Houston, 1989).

Hinrichsen and Storey (1968) showed that maxillary expansion could result in an increase of the overjet of the upper incisors. In such instances a nett maxillary advancement as a result of the treatment, after deducting growth changes, was 3,5 mm (Vardimon, Graber and Voss, 1989). They used interosseous magnetic lateral expansion. A collapse of 1,25 mm in incisor proclination during the relapse phase was related to the lack of interincisor contact to support the upper incisor's new position. A similar incisor relapse was reported by Wertz and Dreskin (1977). Where the incisors do not meet, they will continue to erupt until a stable contact which balances the forces of eruption of the teeth is established. The stability of the incisor contact ultimately depends on the size of the interincisor angle (Houston, 1989).

In a Class II skeletal pattern an increased interincisal angle is usually associated with a deep overbite. In a Class III skeletal pattern with a similar interincisal angle the overbite, however, tends to be reduced (Houston, 1989). In this respect the skeletal pattern is important in its influence on incisor overbite. Variations in the lower incisor inclination may compensate for, or exaggerate, the effects of the anteroposterior incisor apical relationship. Houston (1989) suggests thus, in order to attain maximum overbite stability, the upper root centroid should be at least two millimetres behind the lower incisor edge. This distance is represented as the distance between the perpendicular projections of these points on the maxillary plane (ANS-PNS). The measurement is positive whenever the lower incisor edge is in front of, and negative when it is behind, the upper root centroid.

Overcorrection should be carried out as a precaution against overbite and overjet relapse (Simon and Joondeph, 1973; Berg, 1983).

Early treatment may be necessary in malocclusions with an extreme overjet in order to prevent fracture of the upper anterior teeth. Early treatment may result in a loss of patient co-operation due to the long treatment periods usually involved (Rocke et al., 1980). It may also mask the severity of a malocclusion due to limited tooth movement when most of the permanent teeth are still unerupted. This factor could lead to a nonextraction treatment regime which in turn could result in a bimaxillary protrusion at the end of treatment and eventual relapse (Rocke et al., 1980).

7.5.7 The effect of the third molar on relapse

The role of third molars in post-orthodontic tooth alignment was described by Dewey (1917). He commented that in some subjects mandibular third molars become impacted due to a lack of space. In others these molars create space for their eruption by causing crowding of the anterior teeth. Since then, numerous investigators have attempted to determine whether such a correlation exists.

The presence and eruption of third molars may have an adverse influence on the stability in the mandibular anterior region (Bergstrom and Jensen, 1960; Richardson, 1979; Lindqvist and Thilander, 1982). Bergstrom and Jensen (1961) studied sixty subjects with unilateral molar agenesis and noted more crowding in the quadrants in which third molars were present than in those in which third molars were missing. Sheneman (1968) concluded that patients with congenitally missing third molars showed a greater degree of dental stability than those in whom third molars were present. Schwartz (1975) found a significantly greater forward movement of first molars, particularly in the mandibular arch, when third molars were present. He concluded that mandibular incisor crowding could result from the sagittal force exerted by erupting third molars.

Several investigators have published data to support their belief that third molars play very little, if any, role in causing long-term dental arch changes (Stemm, 1961; Shanley, 1962; Lundström, 1969). In a post-retention study of 75 orthodontically treated patients Kaplan (1973, 1974) found that some degree of lower incisor crowding occurred in the majority of subjects. There was, however, no significant difference in incisor crowding in subjects whose third molars were bilaterally erupted, impacted, or congenitally absent. In addition, he found that observed changes in mandibular arch length and width and in molar and incisor positions were not significantly different amongst the three groups. In conclusion, Kaplan stated that the presence of third molars did not influence post-retention changes in arch dimension, in tooth position, or in mandibular incisor crowding. In a critical review of Kaplan's article (1974), Schulhof (1976) pointed out that, with a larger sample and different statistical tests, Kaplan may have found significant differences between his groups. Rocke et al. (1980) do not assign much importance to the third molars (upper or lower) when looking for the cause of relapse. Mesially inclined lower third molars with their crowns impacted under the distal aspects of second molars, are the effect of crowding, not the cause. It may just be coincidental that the third molars often erupt at the same time that relapse occurs. Perhaps much of this is due to molar mesial migration occurring at the same time as the third molars erupt (Rocke et al., 1980).

Richardson (1980, 1982) found significant mesial movement of the first molars in a group of subjects with intact dental arches and this movement corresponded with an increase in mandibular arch crowding, which occurred over the same time period (13 to 17 years). No difference in the amount of movement, however, was shown between the patients with impacted, and the patients without impacted third molars. In the majority of cases some degree of mandibular incisor crowding occurs after retention, but the change was not significantly different between subjects with or without third molars, suggesting that third molar removal with the objective of alleviating or preventing long term mandibular irregularity may not be justified (Ades, Joondeph, Little and Chapko, 1990).

At present there is no unanimity of opinion or conclusive experimental evidence as to the role of third molars in upsetting mandibular incisor stability (Ades et al., 1990).

7.5.8 Oxytalan fibres and relapse

Oxytalan fibres were first described in 1958 by Fullmer. A similarity between oxytalan fibres and elastic fibres was demonstrated by using specific elastic-fibre stains (Fullmer, Sheetz and Narkates, 1974). Edwards (1968) claimed that following rotational movements of teeth, oxytalan fibres particularly in the supra-crestal area, were more numerous and more clearly defined than in control teeth which were not rotated. The tissue in the interproximal region is a part of the apparatus that supports the teeth in relation to the alveolar process, to the neighbouring tooth as well as to the gingivae. Bowling and Rygh (1988), however, found no evidence to sustain the claim that oxytalan fibres, situated in the transseptal bundles between adjacent teeth, provide any anchoring effect. There seem to be no or very little increase in the oxytalan fibres in the transseptal bundles following orthodontic treatment. However, the area deep to the transseptal bundles, but above the alveolar bone crest, was found to be comparatively rich in oxytalan fibres (Bowling and Rygh, 1988). The oxytalan fibres present appear to be associated more with the blood vessels and it was the opinion of Bowling and Rygh (1988) that the oxytalan fibres were highly unlikely to be responsible for relapse of tooth movements.

7.5.9 Oral habits and relapse

A good reason for breaking oral habits, such as finger-sucking, lies in the fact that they are seldom conducive to occlusal welfare and little inclined to self-correction (Hughes, 1949).

7.5.10 The influence of muscle function on relapse

Orthodontic failures frequently exhibit faulty tongue positions or function (Swinehart, 1950; Baker, 1954). Normal tongue action plays an important role in the formation of the permanent dentition. The co-ordinated function of the tongue, lips, and cheeks maintains a proper equilibrium of muscle forces during the early stages of facial growth and this assures harmony in development of the region. Arch dimension gained through the influences of normal tongue function tends to remain stable (Swinehart, 1950).

There is no reason to believe that lip pressure influences mandibular incisor crowding more in treated than in untreated groups (Owman, Bjerklin and Kurol, 1989). In support of this contention it was shown that lower lip resting pressure does not differ significantly among the Angle classes (Thuer and Ingervall, 1986).

7.6 Aetiology of relapse following orthodontic treatment

Many theories have been proposed to explain the aetiology of relapse and many treatment and retention strategies have been devised to minimize undesirable post-treatment changes (Joondeph and Riedel, 1985). Unfortunately many of these theories and clinical guidelines are based on personal experience and bias, with little or no objective documentation to support them. The results of longitudinal studies have started to cast some light on the post-treatment and post-retention occlusal changes following orthodontic treatment (Shapiro, 1974; Gardner and Chaconas, 1976; Johnston, 1977; Little, Wallen and Riedel, 1981).

The problem has been the inability to determine whether these changes occur primarily as a result of the orthodontic therapy or as part of the normal developmental maturation process (Sinclair and Little, 1983). Perhaps Horowitz and Hixon (1969) have best summarized the problem with their statement, "The significant point is that orthodontic therapy may temporarily alter the course of these continuous physiologic changes and possibly, for a time, even reverse them; however, following mechanotherapy and the period of retention restraint, the developmental maturation process resumes."

7.7 Tooth-size discrepancies in relation to stability (Bolton discrepancy)

Much research has been devoted to defining the causes of malocclusion and the prevention post-treatment relapse. One area which has been examined over the years, with varying conclusions, has been the association of tooth size with crowding. It has been found that in cases with crowding there is a tendency for the incisors to be wider (Richardson, 1977, 1982). In those studies in which statistically significant differences in incisor dimensions were found between crowded and uncrowded cases, the actual mean difference has been in the range of 0.25 mm per incisor (Peck and Peck, 1972b; Swanson, 1973; Norderval, Wisth and Boë, 1975; Doris, Brenhard and Kuftinec, 1981). Other similar studies have found no significant differences in size between crowded and uncrowded incisors (Mills, 1964; Keene and Engle, 1979). Correlation coefficients between incisor dimensions and crowding have been uniformly low (r = 0.46 Lundström, 1955; r = 0.42 Fastlicht, 1970; r = 0.42 Lombardi, 1972; r = 0.24 Smith, Davidson and Gipe, 1982 ; r = 0.42 Gilmore and Little, 1984). Most earlier studies used samples which received no orthodontic treatment, or if treated, the measurements were made from the pre-treatment casts. The effects of orthodontic treatment were thus excluded as well as the possibility that treated subjects may represent a unique sample. The subjects in many of the abovementioned studies were young and it is possible that their well-aligned dentitions became crowded at an older age (Sinclair and Little, 1983).

A decrease in intercanine width in combination with larger tooth size may account for the increased crowding which occurs in the mandibular anterior region (Owman, Bjerklin and Kurol, 1989).

A unilateral Class II problem may be a disguised tooth discrepancy problem. These cases often show high anterior Bolton tooth-size ratios of 80% or more (Bolton, 1958, 1962). If, in such patients a Class I molar relationship is attained, the anterior edge-to-edge or slight overbite will not hold and lower anterior crowding and deepening of the overbite is likely to occur. This is more than relapse and an inexperienced orthodontist may find it difficult to explain the crooked teeth (Swain, 1980).

7.8 Anterior component of force

The importance of an anterior component of occlusal force was first emphasized by Angle (1907) and Stallard (1923). The influence of opposing teeth on mesial drift of monkey teeth was reported by Joho (1973), who found that distally directed forces on mandibular first molars caused distal migration of opposing molars. Teeth are normally slightly mesially tipped and occlusal biting forces may thus create mesially directed forces on the teeth, a phenomenon known as mesial drift (Picton, 1962; Moss and Picton, 1967, 1970; Moyers, 1988). Orthodontic treatment in the upper jaw only ending with a class II molar and class I canine relationship, may create reciprocal forces which are mesially directed in the posterior segments through interdigitation and occlusal forces, and are transmitted to the mandibular arch with resultant increased crowding of the incisors (Owman, Bjerklin and Kurol, 1989).

7.9 Objectives

There exists no longitudinal data in respect to growth or orthodontic treatment for this or another similar sample (Table I). No comparison can thus be made in this regard with other studies noted previously.

Therefore, the objectives of this part of the study were to assess the longitudinal changes following orthodontic treatment in respect of:

i) changes in the occlusion (maxillary teeth to mandibular teeth).

ii) a possible correlation of these changes with irregularity of the lower incisors.

7.10 Materials and methods

The basic description of the materials used and the methods employed to assess the data are documented in Chapter 3 of this thesis.

A brief explanation of the measurements used during this part of the study follows.

7.10.1 Maxillary teeth

The maxillary teeth were studied in terms of:

i) Space shortage in millimetres, in the maxillary arch (MX CROWD) (Moyers, 1988). Similar measurements were used in a study by Sadowsky and Sakols (1982).

ii) Bimolar width in millimetres measured between the centres of the mesiobuccal cusps of the first molars (U6-6I) as well as measured between the widest points on the mid-long axes of the mesiobuccal cusps of the first molars (U6-6B).

iii) The distance in millimetres measured from the distal aspect of the upper first molar,

(a) to pterygoid vertical or the most posterior aspect of the maxilla (PTV) (UM-PTV-MM).

(b) to the centre of the face (CCV) along the facial axis (UM-CCV-MM) (Ricketts et al., 1979).

iv) Upper incisor cephalometric position measured to:

(a) Nasion-Point A line, angular (I-NA-DEG) and millimetres (I-NA-MM) (Steiner, 1953).

(b) Frankfurt horizontal, angular (I/-FH) (Downs, 1948).

(c) Facial axis, angular (I/-FACAX) (Ricketts et al., 1979; Engel et al., 1980).

(d) Point A-Pogonion line, millimetres (I/-APO-MM) (Downs, 1948).

7.10.2 Mandibular teeth

i) Space shortage measured in millimetres to accommodate the mandibular teeth (MD CROWD) (Moyers, 1988). Similar measurements were used in a study by Sadowsky and Sakols (1982).

ii) Curve of Spee measured in millimetres (SPEE) (Moyers, 1988).

iii) Lower intercanine width measured in millimetres from the centres of the cusp tips (L3-3I) as well as the most prominent buccal aspects in the mid-axial dimension (L3-3B) (Moyers et al., 1976).

iv) Irregularity of the lower incisors measured in millimetres (L-IRREG) (Little, 1975).

v) Arch length/ arch depth measured in millimetres (ARCHL) (Moyers et al., 1976) as well as the measurement used by Little (1975) (LITTLE-A).

vi) Lower incisor cephalometric position measured to:

(a) Nasion-Point B line, angular (I-NB-DEG) and millimetres (I-NB-MM) (Steiner, 1953).

(b) Point A-Pogonion line, angular (I-APO-DEG) and millimetres (I-APO-MM) (Williams, 1969, 1985; Ricketts, 1981).

(c) Mandibular plane, angular (IMPA) (Tweed, 1954).

(d) Frankfurt horizontal, angular (FMIA) (Tweed, 1954).

7.10.3 Maxillary and mandibular teeth in occlusion

The occlusion was assessed using the following parameters:

i) Overbite measured in millimetres as the vertical distance between the incisal edges (OBB) and overjet measured in millimetres as the horizontal distance between the buccal surfaces of the maxillary and mandibular incisor teeth (OJB) (Ricketts et al., 1979; Moyers, 1988).

ii) Cephalometric interincisal angle between the upper and lower central incisors (I-I) (Steiner, 1953).

iii) The Bolton discrepancy between the upper and lower teeth, canine to canine (BOLTON A) and first molar to first molar (BOLTON B) (Bolton, 1958, 1962).

iv) The cant of the occlusal plane as an angular measurement to the Sella-Nasion line (OCC-SN) (Steiner, 1953).

v) The molar (MOLAR L and MOLAR R) and canine (CANINE L and CANINE R) relationship (Steiner, 1899, 1907; Andrews, 1972, 1976) assessed according to a similar method employed by Sadowsky and Sakols (1982) (Table II). The variables were noted as described in the literature being Class I, Class II and Class III.

vi) The malocclusion was classified according to the Angle classification system (1899, 1907) with additions as presented by Dewey (Dewey, 1942; Anderson, 1948).

vii) Crossbite assessment of the anterior (ANTXBIT) and the posterior (POSTXBIT) teeth (Moyers, 1988). Parameters similar to Sadowsky and Sakols (1982) were used (Table II).

viii) Total severity score (TMSCORE), a general overview of the degree of severity of the situation (T1, T2 and T3), how it improved and relapsed. This was recorded as a summation of the molar and canine relationship, openbite, crossbites and crowding scores, as well as the direct intercanine and intermolar width measurements. The change in the value of this score is of significance and not the actual numerical value. The change of the score during active treatment is recorded and the deviation from this end-of-treatment value following treatment indicates whether relapse has taken place.

ix) Assessment of the presence of the third molars.

x) Openbite was assessed according to the overbite present. It was recorded as noncontact of incisors or noncontact of the lower incisor with the palatal mucosa (Sadowsky and Sakols, 1982; Moyers, 1988).

xi) Rotations were recorded as the degree of deviation of the mesiodistal centre groove from the mid-mesiodistal centre occlusal line.

The data were subjected to descriptive statistics such as mean and standard deviation for each of the three evaluations. The Friedman test indicated significant differences between the initial and end of treatment observations (T1-T2), initial and final observations (T1-T3) and post-treatment and final observations (T2-T3). The Wilcoxon and the Chi-square tests tested for significant differences between the groups at the three time intervals. Spearman correlation coefficients and the Kruskal-Wallis test showed the relationships of the different variables with the lower incisor irregularity (Little, 1975) at the final observation (T3) (Zar, 1984). The significance level of this part of the study was 0.05.

7.11 Results

The results are set out in Tables XXVIII, XXIX, XXX, XXXI, XXXII and XXXIII.

7.11.1 Maxillary teeth

The maxillary variables which remained stable in the post-orthodontic period (T2-T3), were those which showed no significant change ($p > 0.05$) during this observation period. They were upper molar buccal intermolar width (U6-6B), upper incisor position measured to the NA line, Frankfurt horizontal, the facial axis and the APo line (I-NA-DEG, I/-FH, I/-FACAX and I/-APO-MM). The variables which changed significantly ($p < 0.05$) during this post-orthodontic period were partly influenced by post-pubertal growth changes and included the forward movement of the upper first molars (UM-PTV-MM and UM-CCV-MM) as well as the slight forward movement of the upper incisor measured to the NA line (I-NA-MM) which may be related to mandibular forward growth (Table XXVIII).

During the observation period (T1 to T3) a general assessment was made of how the variables changed throughout the study. Some of the variables showed no significant change ($p > 0.05$) during this period. Those included the upper intermolar widths (U6-6I and U6-6B) and upper incisor position (I-NA-MM, I-NA-DEG, I/-FH and I/-FACAX). The variables showing significant changes from T1 to T3 ($p < 0.05$) were the mesial migration of the upper first molars (UM-PTV-MM and UM-CCV-MM) and the upper incisors measured to APO (I/-APO-MM). The measurement I/-APO-MM indicated a small forward movement of the upper incisors during T2-T3, but this change, although not significant, corresponded with the mesial drift tendency of the teeth and the impingement of the lower incisors upon the upper incisors during forward growth of the mandible as discussed in Chapter 5 (Table XXVIII).

The period of active orthodontic treatment (T1-T2) resulted in various observed changes. Upper first molar inclination or buccal crown torque was slightly increased. This significant change measured a mean increase of 0.59 mm, practically negligible, but even this increase could have affected the post-orthodontic occlusal stability as the measurement at the final observation (T3) was smaller than that at T1, indicating a tendency to relapse in the direction of the original value (T1) after expansion. The upper first molars were moved in a mesial direction, possibly a combination of the normal tendency of mesial migration and the forward movement due to the closing of extraction spaces ($p < 0.05$). The upper incisors were retracted during the active orthodontic treatment (I-NA-MM and I/-APO-MM) ($p < 0.05$), but good torque control maintained the axial inclinations which showed no significant changes (I-NA-DEG, I-FH and I/-APO-MM) (Table XXVIII).

Maxillary crowding was resolved during treatment. Measurements of the crowding mesial of the upper first molars of between 0 to 3.0 mm were taken as clinically acceptable. This measurement also gave an indication whether acceptable incisor alignment was achieved. In all the subjects (88) included in this study this goal was achieved (Table XXX). The severity of the crowding measured at the initial observation (T1) varied according to a scale set out in Table II. Most of the subjects (64.8%) presented with crowding of between 0 to 3.0 mm, while the remaining subjects had more severe crowding measuring 3.5 to 6.0 mm (19.3%) and more than 6.5 mm (15.9%) (Table XXX). The maxillary tooth alignment remained stable during the post-orthodontic period. This was borne out by the fact that all eighty-eight subjects (100%) were categorized in the 0 to 3.0 mm group at the final observation (T3) (Table XXX).

Spearman correlation coefficients indicated whether a weak or strong correlation existed between the lower incisor crowding and the maxillary parameters. The only significant, but weak correlations of the maxillary parameters with the post-orthodontic (T3) lower incisor irregularity (L-IRREG)), were the mesial migration of the upper first molars following active orthodontic treatment (T2) and at the final observation (T3). These correlations were UM-PTV-MM; r = -0.23, p = 0.03 and UM-CCV-MM; r = -0.24, p = 0.02 at T2. Only one parameter (UM-PTV-MM) showed a significant, but weak correlation with the Little Irregularity Index (L-IRREG) at T3 (r = -0.23, p = 0.03) (Table XXXII).

7.11.2 Mandibular teeth

Certain mandibular parameters were significantly ($p < 0.05$) altered during the active orthodontic treatment. They were the arch length (ARCHL and LITTLE-A), the Little Irregularity Index (L-IRREG) as well as the lower incisor position measured to the APo line (I-APO-DEG and I-APO-MM), measured to the Downs (1948) mandibular plane and measured to Frankfurt horizontal as part of the Tweed triangle (Tweed, 1954) (IMPA and FMIA respectively) (Table XXVIII). The non-significant changes ($p > 0.05$) included the lower intercanine dimension (L3-3I and L3-3B) and the lower incisor position measured to the NB line (I-NB-MM and I-NB-DEG) (Table XXVIII).

Of the non-significant changes occurring during the period T1 to T3, one is of special importance, the stable intercanine dimension. This dimension measured at two different positions (L3-3I and L3-3B) remained practically unaltered. Mean changes of 0.2 mm (decrease in L3-3I) and 0.55 mm (increase in L3-3B) occurred from T1 to T2, while both showed decreases during the post-orthodontic period (T2-T3) to values less than the original intercanine distance (0.42 mm and 0.64 mm respectively). The lower incisor parameters (I-NB-DEG, I-NB-MM, I-APO-MM, IMPA and FMIA) remained practically the same as the post-treatment values, indicating good stability during the period from T1 to T3. The significant changes which occured throughout the study (T1-T3) included the only lower incisor parameter change I-APO-DEG (mean 3.53 degrees proclination). Other significant changes were the arch length (ARCHL and LITTLE-A) measurements which showed a continual decrease. This may be as a result of the closing of space between teeth as well as in accordance with natural growth changes. The Little Irregularity Index was significantly ($p = 0.0001$) reduced from a mean value of 4.24 mm to a value of 0.43 mm during treatment (T1-T2) which is within the ideal alignment range described by Little (1975). The index, however, relapsed subsequently during the post-orthodontic observation period (T2-T3) to a mean value of 1.71 mm ($p = 0.0001$). Although an increase in this value was recorded, it still conformed with the normal value advocated by Little (1975) (Table XXVIII).

Most of the variables measured during the post-orthodontic period (T2-T3), showed non-significant changes indicating good stability. Those that remained practically unchanged were the L3-3I, L3-3B, I-NB-MM, I-APO-DEG, I-APO-MM and IMPA (Table XXVIII). The significant changes ($p < 0.05$) included the lingual uprighting of the lower incisor (I-NB-DEG; 1.72 degrees and FMIA; 1.94 degrees). This may be due to the forward mandibular growth during the post-orthodontic period which probably also resulted in the Little Irregularity Index showing a small (1.28 mm), but significant increase during this period (Table XXVIII).

Mandibular crowding, although 100% corrected during active orthodontic treatment, showed some return of crowding during the post-treatment period as measured at T3. The different categories at the intial observation period (T1) were 87.5% of the subjects measured between 0 to 3.0 mm crowding, 11.4% between 3.5 mm to 6.0 mm crowding and 1.1% measured more than 6.5 mm. Only 69.0% of the subjects remained within the accepted range (0 to 3.0 mm) and 31.0% showed more than 3.5 mm at the final observation which included the 13.8% lower arch crowding of more than 6.5 mm (Table XXX).

The curve of Spee measured at the T3 (Table II), showed a similar range to that measured at the initial observation (T1). The deepening of the curve following treatment is illustrated by the 77.1% of subjects measuring a curve of less than 1.5 mm at T2 and then changing to a value of 44.8% of subjects in the normal range at the final observation. The subjects measuring a curve of Spee more than 1.5 mm (39.8%) were reduced to 22.9%, but this increased to 55.2% of subjects at T3. This gives an indication that the curve of Spee tends to return to the original pre-treatment value (Table XXX).

Only the lower incisor parameters I-NB-MM and I-APO-MM at the pre-treatment evaluation showed weak, but significant correlations with the L-IRREG at T3. No other statistically significant correlations could be shown between the mandibular variables (T1-T2, T1-T3, and T2-T3) and lower incisor irregularity at T3 (Table XXXII).

7.11.3 Occlusion

An overview of the changes (T1-T3) show that the overbite (OBB), overjet (OJB), interincisal angle (I-I) and the occlusal plane angle measured to the Sella-Nasion plane (OCC-SN) significantly changed ($p < 0.05$) during this period. The OJB and OBB showed mean reductions of 3.04 mm and 1.41 mm respectively during this period. The interincisal angle increased by a mean value of 2.98 degrees. The occlusal plane angle although slightly increased during active treatment, showed a nett reduction of 1.56 degrees reduction during the period T1 to T3 (Table XXVIII). The only occlusal parameter not changing significantly ($p > 0.05$) during this period was the severity score (TMSCORE) (Table XXVIII). Changes occur in untreated subjects (Sinclair and Little, 1983). These changes may also occur in treated subjects following treatment. The TMSCORE which describes a combination of clinical variables may be affected by these changes following treatment. There is a normal tendency for teeth to return to their original positions following treatment as is shown in the present study. These changes may be the cause why a non-significant change is shown by the TMSCORE the period T1 to T3.

The observed changes during the active orthodontic treatment (T1-T2) indicate that the norms described in the literature were attained. The overjet and overbite were significantly reduced (p = 0.0001) to within the accepted range (0 mm to 3.0 mm) described in Chapter 3 (OJB = mean 2.85 mm; OBB = mean 2.82 mm) (Table XXVIII). The TMSCORE indicated that the corrected dentition had a mean score of 86.44, a significant reduction from the initial value of 88.21 (Table XXVIII). The non-significant changes (p > 0.05) included the interincisal angle which increased by a mean of value 0.65 degrees and the occlusal plane angle which increased by a value mean of 0.96 degrees (Table XXVIII).

A closer look at the critical period which indicates relapse (T2-T3), however, showed most of these variables to remain stable with no significant changes. The OJB increased by a mean value of 0.32 mm, the OBB decreased by a mean value of 0.01 mm and the angle I-I increased from 126.40 degrees to 127.05 degrees. Only the occlusal plane and severity score changed significantly (p = 0.0001 and 0.02 respectively) during this time (Table XXVIII). The occlusal plane angle remained practically unchanged during the active treatment (T1-T2) and post-pubertal growth changes (T2-T3) may have influenced this small reduction of 2.32 degrees. The TMSCORE gives an overall indication of the post-orthodontic changes as it was compiled by a variety of variables (Table II and Chapter 3). The TMSCORE showed a change of 3.75%

during this period which is a significant change, but is negligible from a clinical point of view, illustrating the acceptable stability of the treatment result (Table XXVIII).

Table XXIX portrays the distribution of the Angle classification, an indication of the severity of the malocclusions included in this study. The larger percentage of the subjects in this study was Class II (70.5%). The Bolton tooth-size discrepancy analysis indicates a slightly larger anterior mean ratio of 78.57% (norm noted in the literature by Bolton is 77.2%), but the posterior mean ratio of 91.79% is practically the same as the described norm (91.3%).

Molar and canine relationships remained very stable with only a small percentage of individuals showing relapse. At the pre-treatment observation (T1) 51.2% of the left first molars and 57.9% of the right first molars were not in a Class I relationship. The canines showed much higher percentages not in Class I (left 80.7% and right 79.5%). The molar and canine relationships were practically all (MOLAR L 94.3%, MOLAR R 93.2% and CANINE L 94.3%, CANINE R 93.2%) corrected to a Class I relationship during the orthodontic treatment (T1-T2). At the final observation (T3) all these parameters showed values of over 90% (Table XXX).

A small percentage of individuals who showed an anterior openbite (OPENBIT) at the pre-treatment observation (T1) showed a relapse of the corrected dentition, but a nett improvement was recorded (22.8% with openbites at T1, 5.6% at T2 and 9.1% at T3) (Table XXX).

The anterior crossbites which were observed at the initial observation (T1) were all (100%) corrected during the active orthodontic treatment (T1-T2). A small relapse occurred during the post-orthodontic period. Only 5.7% of individuals measured one to two anterior teeth in crossbite at the final observation (T3) (Table XXX). Posterior crossbites, however, were not all corrected during treatment and 5.6% of individuals still showed posterior crossbites followinfg active treatment. The corrections (94.3% showing no crossbite) remained reasonably stable with only a very small percentage showing relapse (6.9%) (Table XXX).

Although practically all the rotations were corrected (T2: 92.0% of individuals with no rotations, 8.0% showing rotations between 15 degrees and 90 degrees), relapses were recorded at the final observation (T3). Of the corrected rotations observed at the post-treatment assessments (T2), 57.5% of the individuals showed no rotations, 41.4% showed rotations between 15 degrees and 90 degrees and only one individual showed rotations of more than 90 degrees at the final observation (T3) (Table XXX).

A large number (80.7%) of the third molars were not present in the mouth at T3 (Table XXXI).

The Spearman correlation coefficients set out in Table XXXII showed no significant relationships ($r < 0.2$ and $p > 0.05$) between the occlusal metrical variables (OJB, OBB, I-I, BOLTON A, BOLTON B, OCC-SN and TMSCORE) at the various observations (T1, T2 and T3) and lower incisor irregularity (L-IRREG) at the final observation (T3). The Kruskal-Wallis test was used to indicate whether a significant relationship existed between the non-metrical variables (MOLAR L and R, CANINE L and R, ANTXBIT, POSTXBIT and WISDOMS) and the lower incisor irregularity measured at the final observation (T3). No significant relationships could be shown for these parameters ($p > 0.05$) (Table XXXIII)

7.12 Discussion

Occlusal analysis is a vital part of the original diagnosis and a necessary ongoing procedure in assessing treatment progress or results. There is no diagnostic way to measure or to accurately estimate malocclusion, nor to decide how closely treatment has approached good end results, until we have first decided what good occlusion is. Most orthodontists focused on two areas only: molar relationship and interincisal angle. The remaining components of good occlusion have not been objectified; as a result, there are almost as many static occlusal schemes as there are orthodontists (Andrews, 1976).

TABLE XXVIII

DESCRIPTIVE STATISTICS OF METRICAL DATA IN RESPECT TO THE OCCLUSION
(Friedman test included)

	T1		T2		T3			T1-T2	T1-T3	T2-T3
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	p-value	Pairwise differences		
MAXILLA:										
U6-6I	49.60	3.63	50.19	3.79	49.51	3.31	0.05	-	x	+
U6-6B	53.13	3.57	54.26	5.42	53.02	3.16	0.29	x	x	x
UM-PTV-MM	17.10	3.75	20.23	4.86	23.02	4.49	0.0001	-	-	-
UM-CCV-MM	15.96	3.72	18.86	4.93	21.46	4.64	0.0001	-	-	-
I-NA-DEG	22.99	9.09	22.60	8.44	22.35	7.48	0.83	x	x	x
I-NA-MM	4.14	2.86	2.84	2.61	3.49	2.60	0.002	+	x	-
I/-FH	114.41	8.76	112.55	8.10	112.65	7.09	0.14	x	x	x
I/-FACAX	4.02	8.65	5.57	7.29	6.19	6.08	0.19	x	x	x
I/-APO-MM	7.29	3.13	4.31	1.73	4.42	1.93	0.0001	+	+	x
MANDIBLE:										
L3-3I	26.19	1.72	25.99	1.69	25.77	1.88	0.08	x	x	x
L3-3B	30.52	1.90	31.07	3.14	30.16	2.11	0.10	x	x	x
ARCHL	23.50	2.37	20.75	3.19	20.01	3.52	0.0001	x	x	x
LITTLE-A	61.10	4.31	56.69	6.83	54.99	7.05	0.0001	+	+	+
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	-
I-NB-DEG	27.22	6.41	28.43	5.08	26.71	4.72	0.03	x	x	+
I-NB-MM	3.89	2.11	4.32	1.63	4.04	1.65	0.15	x	x	x
I-APO-DEG	23.75	5.17	27.71	4.68	27.38	4.65	0.0001	-	-	x
I-APO-MM	0.42	2.86	1.29	1.90	0.85	1.93	0.03	-	x	x
IMPA	96.79	10.68	98.54	6.64	97.79	6.68	0.05	-	x	x
FMIA	60.42	6.84	59.18	5.72	60.92	8.86	0.001	+	x	-

CCLUSION:

JB	6.21	3.29	2.85	0.85	3.17	1.23	0.0001	+	+	x
BB	4.22	1.48	2.82	0.97	2.81	1.09	0.0001	+	+	x
-I	126.40	11.05	127.05	9.34	129.38	7.79	0.03	x	-	x
CC-SN	16.89	5.22	17.65	4.19	15.33	4.92	0.0001	x	+	+
MSCORE	88.21	5.63	86.44	5.19	89.68	5.85	0.02	+	x	-

.D. = Standard deviation
= Significant, $p < 0.05$ (TI > T2, T3)
= Significant, $p < 0.05$ (TI < T2, T3)
= Not significant, $p > 0.05$

TABLE XXIX

FREQUENCY DISTRIBUTION (prevalence) OF ANGLE CLASSIFICATION (molar relationship) AND BOLTON TOOTH-SIZE DISCREPANCY

i) Classification T1:

VARIABLE	N	
CLASS I	24	(27.3%)
CLASS II	62	(70.5%)
CLASS III	2	(2.3%)

N = Sample size
Percentage representation (frequency) in parentheses

ii) Bolton tooth-size discrepancy T1:

VARIABLE	FREQUENCY
BOLTON A	78.57% (2.14%)
BOLTON B	91.79% (2.04%)

Standard deviation in parentheses

TABLE XXX

FREQUENCY DISTRIBUTION OF CROWDING AND OCCLUSAL PARAMETERS

VARIABLE	T1 N	T2 N	T3 N
MXCROWD:			
0	57 (64.8%)	88 (100%)	88 (100%)
1	17 (19.3%)		
2	14 (15.9%)		
MDCROWD:			
0	77 (87.5%)	88 (100%)	61 (69.0%)
1	10 (11.4%)		15 (17.2%)
2	1 (1.1%)		12 (13.8%)
SPEE:			
0	53 (60.2%)	68 (77.1%)	40 (44.8%)
1	33 (37.5%)	19 (21.8%)	46 (52.9%)
2	2 (2.3%)	1 (1.1%)	2 (2.3%)
MOLAR L:			
0	43 (48.9%)	83 (94.3%)	80 (90.9%)
2	21 (23.9%)	3 (3.4%)	5 (5.7%)
3	24 (27.3%)	2 (2.3%)	3 (3.4%)
MOLAR R:			
0	37 (42.0%)	82 (93.2%)	82 (93.2%)
2	25 (28.4%)	4 (4.5%)	3 (3.4%)
3	26 (29.5%)	2 (2.3%)	3 (3.4%)
CANINE L:			
0	17 (19.3%)	83 (94.3%)	80 (90.9%)
2	43 (48.9%)	4 (4.5%)	6 (6.8%)
3	28 (31.8%)	1 (1.1%)	2 (2.3%)
CANINE R:			
0	18 (20.5%)	82 (93.2%)	80 (90.9%)
2	45 (51.1%)	6 (6.8%)	7 (8.0%)
3	25 (28.4%)	0	1 (1.1%)
OPENBIT:			
0	68 (77.3%)	82 (93.2%)	76 (86.4%)
1	18 (20.5%)	6 (6.8%)	11 (12.5%)
2	2 (2.3%)		1 (1.1%)

ANTXBIT:			
0	72 (81.8%)	88 (100%)	83 (94.3%)
1	13 (14.8%)		5 (5.7%)
2	3 (3.4%)		
POSTXBIT:			
0	58 (65.9%)	83 (94.3%)	80 (90.9%)
1	21 (23.9%)	4 (4.5%)	5 (5.7%)
2	9 (10.2%)	1 (1.1%)	3 (3.4%)
ROTATE:			
0	66 (75.0%)	81 (92.0%)	51 (57.5%)
1	21 (23.9%)	7 (8.0%)	36 (41.4%)
2	1 (1.1%)		1 (1.1%)

N = Sample size
Percentage representation (frequency) in parentheses

TABLE XXXI

FREQUENCY OF MAXILLARY AND MANDIBULAR THIRD MOLARS PRESENT AT T3

VARIABLE	N
Third molars not present	71 (80.7%)
Third molars present	17 (19.3%)

N = Sample size
Percentage representation (frequency) in parentheses

TABLE XXXII

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE MEASURED OCCLUSAL VARIABLES AT T1,T2 AND T3 TO THE IRREGULARITY OF THE MANDIBULAR INCISORS AT T3

L_IRREG

	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
MAXILLA:						
MX CROWD	0.13	0.45	----		-0.08	0.56
U6-6I	0.03	0.78	0.08	0.49	0.09	0.42
U6-6B	0.002	0.98	0.06	0.59	0.08	0.46
UM-PTV-MM	-0.17	0.11	-0.23	0.03	-0.23	0.03
UM-CCV-MM	-0.18	0.09	-0.24	0.02	-0.17	0.11
I-NA-DEG	-0.01	0.96	0.07	0.53	0.09	0.42
I-NA-MM	0.04	0.74	0.08	0.45	0.08	0.46
I/-FH	-0.03	0.79	-0.04	0.71	-0.03	0.79
I/-FACAX	-0.03	0.81	-0.04	0.69	-0.09	0.39
I/-APO-MM	0.08	0.48	0.10	0.34	0.11	0.32
MANDIBLE:						
MD CROWD	-0.22	0.22	----		0.04	0.81
SPEE	0.06	0.64	0.01	0.93	-0.02	0.87
L3-3I	0.05	0.64	-0.01	0.91	0.16	0.14
L3-3B	-0.01	0.91	-0.06	0.58	0.06	0.58
ARCH-L	-0.12	0.27	0.04	0.72	0.01	0.89
LITTLE-A	-0.11	0.32	0.06	0.55	-0.01	0.93
I-NB-DEG	-0.16	0.14	-0.08	0.43	-0.06	0.57
I-NB-MM	-0.07	0.05	0.13	0.23	0.03	0.75
I-APO-DEG	-0.20	0.06	-0.04	0.69	-0.05	0.63
I-APO-MM	-0.21	0.05	-0.04	0.69	-0.07	0.52
IMPA	-0.07	0.49	0.01	0.91	0.05	0.65
FMIA	0.07	0.53	-0.10	0.34	-0.10	0.37
OCCLUSION:						
OJB	0.20	0.06	0.09	0.43	0.04	0.75
OBB	0.11	0.31	0.13	0.23	0.11	0.29
I-I	0.06	0.61	-0.02	0.85	-0.09	0.39
BOLTON A	-0.02	0.92	----		0.03	0.80
BOLTON B	0.01	0.97	----		0.03	0.80
OCC-SN	0.05	0.65	0.10	0.33	0.11	0.33
TMSCORE	0.09	0.39	0.01	0.92	0.12	0.26

r = Spearman correlation coefficient
p = Significance level, $p < 0.05$

TABLE XXXIII

KRUSKAL-WALLIS TEST COMPARING SIGNIFICANT RELATIONSHIPS OF OCCLUSAL VARIABLES AT T1, T2 AND T3 TO THE IRREGULARITY OF THE LOWER INCISORS AT T3

	L_IRREG		
	T1	T2	T3
VARIABLE	p	p	p
OCCLUSION:			
MOLAR L	0.34	0.55	0.45
MOLAR R	0.05	0.61	0.34
CANINE L	0.13	0.88	0.13
CANINE R	0.13	0.88	0.13
ANTXBIT	0.69	0.79	0.79
POSTXBIT	0.85	0.12	0.07
WISDOMS	----	----	0.51

p = Significance level, $p < 0.05$

The implications of a wide diversity of opinion about fundamental standards should disturb all orthodontists. It should be a matter of personal pride for orthodontists to provide treatment which is directed toward known and well founded objectives, and to deliver complete treatment, with every tooth optimally positioned according to static and anatomical occlusal standards which are entirely compatible with the requirements of functional occlusion (D'Amico, 1958; Andrews, 1972, 1976; Dawson, 1974; Roth, 1976, 1981; McHorris, 1979; Alexander, 1986). Orthodontists consider it to be axiomatic that good occlusion is one of the benefits patients recieve from orthodontic treatment. However, the post-treatment maintenance of a healthy stomatognathic system and the attainment of a stable post-orthodontic treatment result are tasks which can not be taken lightly.

Attaining tooth alignment during treatment and then maintaining this tooth alignment, as well as oral health and comfort in the post-orthodontic phase, depends on many factors such as:

i) the physical and psychological state of the subject.
ii) oral and dental care.
iii) the quality of the orthodontic treatment in terms of, not only aesthetics and anatomical norms, but also of muscle balance, oral habits, functional airway, the periodontium and the functional harmony of the occlusion and its effect on the musculature and the temporomandibular joints (Roth, 1976).

Crowding of lower incisor teeth, following active orthodontic treatment, is a problem encountered frequently in orthodontic practice (Little, 1990). Little, Riedel and Artun (1988) noted that the lower incisor irregularity as measured by Little (1975) continuously changed during a period of ±20 years (mean values: pre-treatment = 7.41mm; post-treatment = 1.66mm; 10 years post-retention = 5.25mm; 20 years post-retention = 6.02mm). It appears from these values that the lower incisor irregularity does not significantly change from a clinical point of view following the 10 year post-retention period. The present study showed an increase of 1.28mm (L-IRREG: T2 = 0.43mm; T3 = 1.71mm) (Table XXVIII) in this parameter following a 5 year post-retention period (7 year post-orthodontic). A better mean correction was attained for the malocclusions of the present study when judging the alignment of the lower incisors (Little et al., 1988 L-IRREG T2 = 1.66mm; Present study L-IRREG T2 = 0.43mm). A prospective speculation in respect to the Little Irregularity Index (Little, 1975) may see this index increase ±39.22% during the post-orthodontic interval if compared to the increase of the Little et al. (1988) study. It is however doubtful whether this would occur to the same extent seeing that better alignment was attained at the end of the treatment. The latter more positive conclusion is in agreement with some other studies (Sandusky, 1983; Udhe, Sadowsky and BeGole, 1983). The symptom of crowding (the phenomenon of post-treatment crowding regarded as an indication of relapse) has little meaning, unless it is related to the other parameters constituting the occlusion. Successful therapy may depend on the orthodontist's ability to evaluate these factors contributing to the overall occlusal pattern.

Maxillary bimolar width remains virtually unchanged during normal growth from ten to eighteen years (Table XXIV). Maxillary arches can be more easily altered during orthodontic treatment than can mandibular arches (Moyers, 1988). Maxillary molar width was increased slightly during the period of active treatment (T1-T2). This mean widening was in the the order of a 0.59mm (U6-6I) and 1.13mm (U6-6B). Although only the incisal mensuration (U6-6I) showed a significant difference in the period between T2 and T3, both returned to a mean of 0.11mm of the original measurment. During the post-treatment period (T2-T3) the upper first molar rotated mesio-palataly as a result of the continual mesial migration tendency attributed to the dentition (Picton, 1962; Moss and Picton, 1967, 1972; Moyers, 1988), thus causing the U6-6I variable to decrease. This intermolar dimension was, however, increased as noted in Table XXVIII during T1 to T2 and restriction by the buccal alveolar cortical plate and buccinator muscles, could be the cause for the slight relapse during the post-treatment period to a value less than the original ($p < 0.05$). The upper molars showed continual mesial movement. The UM-PTV-MM and UM-CCV-MM distances increased in the period from T1 to T3 (Table XXVIII). These findings are closely linked with the decrease in arch length (Moyers et al., 1976), mesial migration of teeth (Enlow, 1968; Moss and Picton, 1972; Moyers, 1988) and although highly controversial, also with the development and eruption of the third molars (Richarson, 1980). The results of a study on untreated individuals (Sinclair and Little, 1985) showed that with a bite-closing rotation of the jaws similar forward molar movements were experienced.

Various measurements of the upper incisor position were assessed (Table XXVIII). All of the upper incisors were treated to within acceptable clinical parameters (Downs, 1948; Steiner, 1953; Riolo et al., 1974; Ricketts et al., 1979; Engel et al., 1980). Small changes are to be expected in an occlusion surrounded by a sound periodontium, but although measurable changes were noted, none were significant except the I-NA-MM and I/-APO-MM (Table XXVIII). The I-NA-MM measurement changed 0.65mm during the post-orthodontic period (T2-T3), which is clinically almost negligible. A similar small forward movement, which was not significant during this period (T2-T3), was portrayed with the I/-APO-MM variable (mean 0.11 mm). A significant change was shown in the overview from T1 to T3. It can, however, be speculated that as the dentition migrates mesially, a slightly more protrusive measurement to the lines NA and APo would be measured. Mandibular forward growth during the post-orthodontic period may also have contributed to this minimal forward movement of the upper incisor.

The variable which could contribute significantly to relapse of treatment was the continual mesial movement of the upper molars. They not only moved mesially during treatment (T1-T2), but continued in a forward direction following treatment (T2-T3). The most significant incisor change as noted could have been the result of this molar drift. The upper arch was treated to practically perfect alignment (100% achieved a crowding mean measurement of between 0 and 3.0mm). This percentage of success was maintained at T3 (Table XXX). Findings in respect of the influence of these changes on the lower incisor irregularity (T1-T3) showed only upper molar mesial movement which significantly, but weakly correlated with the Little Irregularity Index (Little, 1975) at T3 (Table XXXII).

The mandibular intercanine dimension in the secondary dentition remains constant with growth (Table XXIII). As is recommended in the literature, the mandibular intercanine width (L3-3I and L3-3B) was maintained during treatment (Riedel, 1960; Schulof, Lestrel, Walters and Schuler, 1978). Although not significantly ($p > 0.05$), it did decrese to a value narrower than the original dimension at T3. This finding is in keeping with studies by Dona (1952), Arnold (1963), Welch (1965), Shapiro (1974), Gardner and Chaconas (1976) and Little, Wallen and Riedel (1981). The intercanine distance also decreased to a value narrower than the original observation in untreated normal individuals (Table XXIII). The report of the work of Shields, Little and Chapko (1985) showed no correlation between this measurement and lower incisor crowding post-treatment, but according to the findings of the present and other studies (Strang, 1949; Gardner and Chaconas, 1976) a stable intercanine dimension could be a contributing factor to denture stability since it will keep the arch circumference between the lower canines constant, and thus provide the necessary space for uncrowded lower incisors.

The position of the lower incisor tip was treated to ideal norms (Steiner, 1953; Ricketts, 1981). The axial inclination mensuration (I-NB-MM, I-APO-DEG, IMPA and FMIA) indicated, however, that the lower incisor was proclined slightly beyond the upper limit of the norms (Steiner, 1953; Tweed, 1954 and Ricketts, 1981). These positional measurements remained reasonably stable. No significant changes, except for I-NB-DEG and FMIA were measured at the final observation (T3) (Table XXVIII). The lower incisor changed to a more upright position following treatment (T3) which could decrease the arch circumference in the anterior area. This decrease in arch circumference could cause the lower incisors to relapse into a crowded situation. The situation is aggravated by the continual decrease (T1-T3) in the arch length (ARCHL and LITTLE-A) (Table XXVIII). The decrease in the arch length could be due to closing of spaces during treatment as well as the natural phenomenon of mesial migration of the dentition noted earlier. This is borne out by the mandibular dentition, having been ideally aligned in all the patients during treatment, but showing only 69.0% of subjects remaining within clinically acceptable alignment at T3 (13.8% of the subjects showed lower incisor crowding of more than 6.5 mm at T3) (Table XXX). This continual decrease in mandibular arch length is also observed during normal growth and maturation of the dentition (Table XXV). In only 77.1% of the dentitions studied was the ideal curve of Spee, of less than 1.5mm (Andrews, 1972, 1976), achieved at the end of treatment (T2). This morphological trait deteriorated so that eventually only 44.8% of the subjects were within the set norm. It must, however, be mentioned that only a very small percentage of the patients manifested with a very deep curve (deeper than 4mm) at the end of treatment (T2) and even at the final observation (T3) (Table XXX).

Rotations which were corrected during treatment also tend to return towards original positions. Of the 92.0% success rate achieved at the end of treatment (T2) only just more than half (57.5%) remained stable (Table XXX). Crowding of the lower incisors post-orthodontically, accounts partly for the rotations observed in this phase. Rotated posterior teeth take up more space in the dental arch (Andrews, 1972, 1976) and could have been a contributing factor towards the increase in the lower incisor irregularity (Little, 1975) which was noted post-treatment. No fiberotomies as described by Edwards (1970), were performed in any of the cases studied.

The uprighting of the lower incisors, a deepening of the curve of Spee, the relapse of rotations in combination with the continual decrease in arch length during post-orthodontic growth (T2-T3), may largerly account for the increase in the Little Irregularity Index (Little, 1975) from a mean of 0.43 mm to one of 1.71 mm (Table XXVIII). It will be noted that the mean value for this parameter at T3 is significantly better than the mean for the Little

Irregularity Index recorded prior to the treatment (T1). Although some relapse or rebound took place (L-IRREG from T2-T3, $p < 0.05$), the mean value for the Little Irregularity Index at the final observation (T3), is still within acceptable clinical norms (Little, 1975). Other studies, which also included assessments of untreated normals, showed similar results (Barrow and White, 1952; Moorrees, 1959; Lundström, 1969; Little, Wallen and Riedel, 1981; Sinclair and Little, 1983). Björk and Skieller (1972) and Fisk (1966) referred to the forward growth of the mandible as the cause of the lower incisor crowding. Similar conclusions were made in Chapter 5 of this thesis.

All the mandibular variables were correlated with the Little Irregularity Index at the end of the post-orthodontic period (T3). No significant correlations were shown between the lower incisor irregularity (L-IRREG) and the mandibular metrical characters ($p > 0.05$) (Table XXXII). This is in accordance with the study of Carmen (1978) and Little and Sinclair (1983, 1985).

Prior to treatment the teeth in occlusion presented in the following Angle (1907) relationships: Class I = 27.3%, Class II = 70.5% and Class III = 2.3% (Table XXIX). As a result of the orthodontic treatment a correction to a Class I molar relationship was achieved in almost all the subjects (94.3% left and 93.2% right). The findings in respect of the canine relationships were in close agreement with those recorded for the molar teeth (Table XXX). More than 90% of both molar and canine Class I relationships were maintained post-treatment which indicates good stability. Similar results were recorded by Behrents et al. (1989). No significant relationship ($p > 0.05$) could be established between the Little Irregularity Index (Little, 1975) at the final observation (T3) and the molar and canine relationships at the various time intervals (Table XXXII).

The mean Bolton tooth-size discrepancy recorded in this study (Table XXIX) was practically identical to the norms described by Bolton (1958, 1962) for American Caucasians. No significant correlation was shown for this measurement with lower incisor irregularity (Table XXXII). The mean anterior tooth-size discrepancy ratio was slightly larger (1.32%) than Bolton's norm for this region and could, even in this low value, have contributed to the lower incisor crowding which was noted at the end of the post-orthodontic phase. The overall finding, however, eliminates the abovementioned variable as a cause of lower incisor crowding.

As a result of the treatment, overjet and overbite (OJB and OBB) were significantly corrected to acceptable norms (Ricketts et al., 1979; Moyers, 1988). The overjet and overbite norms for various ages during growth are portrayed in Tables XXVI and XXVII. Overjet tends to decrease during normal growth, but overbite shows an overall increase in females and males up to fourteen years of age and then a slight decrease in males with the females continuing to increase (Tables XXVI and XXVII). These two parameters did not change significantly after the removal of the appliances (T2-T3) (Table XXVIII). It was shown in other long-term studies that overjet and overbite tend to improve or degenerate completely following treatment (Ludwig, 1967; Simon and Joondeph, 1973; Lagerstrom, 1980; Berg, 1983). Moyers et al. (1976) noted in untreated normals that these parameters increased initially, but decreased from thirteen to twenty years of age, resulting in minimal overall changes. Correct overjet and overbite in combination with acceptable upper incisor torque (axial inclination) values and a normal interincisal angle (I-I) are imperative in achieving a Class I occlusion (Andrews, 1972, 1976). Positive correlations between these parameters were shown by Popovich (1955), Backlund (1960), Solow (1966), Ludwig (1967) and Simon and Joondeph (1973). In the present study the interincisal angle was within prescribed norms for all phases studied. An obtuse interincisal angle is often associated with a deep overbite (Houston, 1989). Although not significantly so, the interincisal angle increased from a mean of 127.05 degrees at the end of treatment (T2) to a mean of 129.38 degrees at the final observation (T3). This change can possibly be ascribed to the recorded uprighting of the lower incisor teeth. Although the lower incisors showed slight uprighting following treatment, the mean measured values for these incisor positions were slightly more proclined than the mean for the norms described in the literature. The upper incisor positions remained within the norms throughout the period studied. The slightly more proclined lower incisors could play a role in the stability of the overbite which is in contradiction to many other studies. Clinically, OJB and OBB, remained reasonably stable (Table XXVIII). No significant correlation could be shown between these two variables and lower incisor irregularity (Table XXXII).

Twenty subjects (22.8%) initially presented with anterior openbite problems. Of these fourteen subjects (70.0%) were corrected to normal overbite and overjet relationships. Six subjects (30.0%) relapsed (Table XXX). No overt habits were present at the end of the post-orthodontic phase (T3), but it is possible that some abnormal muscle function or habit, which caused the openbite, could still have been present in the immediate post-retention period before the final records were taken (mean post-retention time interval 5 years; mean post-orthodontic time interval 7 years). Oral habits are seldom conducive to normal occlusion (Hughes, 1949; Swinehart, 1950; Baker, 1954; Proffit, 1986; Moyers, 1988).

The mean occlusal plane to anterior cranial base angle (OCC-SN) was slightly more obtuse at the end of treatment (Table XXVIII), possibly as a result of Class II mechanics. This non-significant change from T1 to T2 was followed by a significant change ($p = 0.0001$) from T2 to T3. This change could be attributed to the closing rotation of the lower jaw during the post-pubertal phase and may have influenced the slight relapse in lower incisor alignment. Björk and Skieller (1972) noted similar findings. The mean occlusal plane angle became more acute and as a result of this occurance became closer to the Steiner (1953) norm of fourteen degrees (T3 = mean 15.33 degrees). During anchorage preparation, as was advocated by Tweed (1966), it was suggested that the preparation of the occlusal plane (up forward and down posterior) in order to withstand Class II elastic intermaxillary traction during the latter phases of treatment and to eventually change back to its normal position after active treatment. This increase of OCC-SN during treatment and the return to a value below the original observed value could thus possibly be ascribed to similar changes. Clinicians should endeavour not to change the original occlusal plane angle with their treatment (Tweed, 1966). Although relatively small, this OCC-SN change, however, was significant (Table XXVIII) and although relatively small, showed a tendency to return to the original mean value. This change could not be held responsible for contributing to lower incisor irregularity, as no significant statistical correlation could be shown between these two variables (Table XXXII).

The mean anterior crossbite at the pre-treatment observation was totally corrected (100%) (Table XXX). Only 5.7% of subjects showed a return of anterior crossbite at the final observation (T3). Of the 94.3% subjects in whom posterior crossbites were completely corrected during treatment, 3.4% relapsed. There was originally thirty subjects (34.1%) with posterior crossbites (T1), five subjects were not corrected during treatment for some unknown reason and eight subjects presented with posterior crossbites at the final observation (T3). A variety of causes may be responsible for the relapse of a crossbite. These include, amongst others: impaired upper airway, failing to overcorrect the problem during treatment, not achieving correct axial inclination of the corrected teeth or too short a retention time. No significant relationship could be shown between lower incisor irregularity and crossbites (Table XXXIII).

The occlusal traits were assessed and expressed as total malocclusion scores (TMSCORE). These scores did not change significantly from T1 to T3 and it is immediately assumed that the there was no benefit from the orthodontic treatment. This is not true because the change is reflected by the treated occlusion (T3) tending to return to the original malocclusion (T1). However, a significant change was shown during the active treatment (T1-T2) and during the post-orthodontic period (T2-T3) (Table XXVIII), but the post-orthodontic change did not equal the treatment change thus showing a nett correction (Table XXVIII). The change following active treatment could be partly ascribed to growth changes and/or partly to rebound of treated variables post-treatment. It was not possible to show significant correlations between the malocclusion scores and lower incisor irregularity (Table XXXII).

It can only be a matter of speculation whether third molars cause lower incisor crowding following treatment. According to Table XXXI there was 80.7% of the sample who had no third molars present, being either congenitally absent or having been removed following the active orthodontic treatment. This high incidence of missing third molars may have helped to keep the Little Irregularity Index within acceptable clinical norms. There is no definite confirmation that the third molars cause or do not cause lower incisor crowding following treatment. There are results reporting in favour of the third molars as an aetiological factor of late lower incisor crowding (Bergstrom and Jensen, 1960, 1961; Sheneman, 1968; Schwartz, 1975; Schulhof, 1976; Richardson, 1977, 1979, 1980; Ricketts et al., 1979; Lindqvist and Thilander, 1982) and there are reports in the literature that ascribe no significance to the third molars as factors in post-treatment lower incisor relapse (Stemm, 1961; Shanley, 1962; Lundström, 1969; Kaplan, 1973, 1974; Rocke et al., 1980; Ades et al., 1990). No significant relationship could be shown between the absence or presence of third molars and late lower incisor crowding (Little Irregularity Index) at the final observation (T3) (Table XXXIII).

A general overview of the dental changes noted in this study, leads to the conclusion that a major contributing factor leading to the clinically acceptable lower incisor crowding following active treatment, was the ability of the operators to keep arch dimensions within the described norms during treatment. Arch width dimensions should thus be maintained in order to assist with the achievement of successful post-orthodontic results. A post-treatment occlusion with a flat curve of Spee and no rotations could be stable following orthodontic treatment. Correctly maintained arch dimensions as well as accurately positioned teeth on basal bone calls for superb orthodontic technique. Growth changes outside the scope of the treatment period and thus not within the control of the orthodontists, may have played a role in causing the slight lower incisor crowding recorded at the final observation. The variables showing the worst changes following removal of the appliances were changes of a maturational nature that included decreasing arch lengths and mesial molar migration ($p < 0.0001$; Table XXVIII). The clinically acceptable level of stability achieved at the end of the post-orthodontic period (T3), underwrites good overall orthodontic technique. This includes correct diagnosis, setting a meticulous treatment plan and the support of an excellent mechanical technique.

7.13 Conclusions

1. A continual decrease in arch length post-treatment may contribute to lower incisor crowding.
2. The ideal cephalometric norms for incisor position should be adhered to as they tend to remain stable if kept within clinical norms.
3. Arch width dimensions should be maintained or if changed, rather be slightly reduced as this dimension decreases in the long-term.
4. Mesial movement of the dentition was the only variable which correlated significantly, but weakly with lower incisor irregularity at the final observation (T3).
5. No strong significant correlations could be shown between lower incisor crowding and the other dental variables measured in this study.

6. Lower incisor position was slightly more proclined in respect to the mean normal values, but was still within clinically acceptable limits and especially so when it was assessed in comparison to the change in the post-orthodontic Little Irregularity Index.
7. Overbite remained unchanged during the post-retention interval which is in contrast to other studies.
8. Better long-term stability of the Little Irregularity Index was shown when compared to other well-known studies.

A LONGITUDINAL STUDY OF THE STABILITY OF THE DENTITION FOLLOWING ORTHODONTIC TREATMENT

VOLUME 2

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Thesis submitted to the Faculty of Dentistry,

University of Stellenbosch

in fulfilment of the requirements

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CHAPTER 8

A LONGITUDINAL EVALUATION OF THE ANTERIOR BORDER OF THE DENTITION AND ITS RELATIONSHIP TO LOWER INCISOR IRREGULARITY

8.1 Introduction

Orthodontists in clinical practice have directed specific attention to the mandibular arch as being greatly limiting, and therefore of primary consideration, in diagnosis (Schulhof, Lestrel, Walters and Schuler, 1978).

The question as to whether it is possible for the mandibular cuspids to remain stable after orthodontic movement is often raised in discussions regarding the stability of post-treatment results. A study of orthodontic patients approximately 7 years following active treatment shed some light on this question (Gardner and Chaconas, 1976). Accordingly it was shown that mandibular molars may be expanded in the order of 2mm with little relapse, while the majority of cuspids(60%) showed relapse when expanded as little as 1 mm. Extraction and nonextraction cases were subject to similar incidences of relapse which is in agreement with the findings of Riedel (1960) who believed that lower cuspids can not be permanently expanded. Although the literature provides few indications for predicting which cases will tolerate expansion, there appears to be a tendency for the Class II division 2 cases to show a greater potential for remaining stable following some increase in lower arch width (Riedel, 1960; Shapiro, 1974).

Schulhof and associates (1978) derived a formula which indicates that patients with brachyfacial patterns have wider dental arches than those with dolichofacial patterns. Strang (1949) stated that the intercanine width of the mandibular arch is an infallible guide to balance of the muscles which dictate the limit of denture expansion in this area. Others have also reported that intercanine width has a tendency to remain the same or return to the original dimensions after treatment (Dona, 1952; Arnold, 1963; Welch, 1965).

A method for predetermining the ideal dental arch width has become known as "Pont's Index" (Pont, 1909) and was used to study 91 Navajo children with ideal occlusions (Worms et al., 1969). At a confidence level of 1%, there was a significant difference between observed and calculated premolar and molar widths. Worms et al. (1969) and others concluded that the reliability of Pont's index as a diagnostic tool in orthodontics is highly questionable (Greve, 1933; Hotz, 1961; Smyth and Young, 1932; Korkhaus, 1939; Joondeph, Riedel and Moore, 1970). The use of the index was brought into focus by practitioners who depend almost entirely on it for determining proper arch width and who as a result may thus be expanding the mandibular teeth beyond their stable limits.

The determination of ideal arch form is greatly dependent on the position of the cuspids which represent the cornerstones of the dental arches (Andria and Dias, 1978). In general orthodontists should not lose sight of the fact that our biggest problem seems to be arch width (Howes, 1957) and it may be pertinent to note some other observations on this controversial issue.

Walter (1953, 1962) studied the stability of the dental arches after expansion, taking measurements before, at the end of treatment, and several years after retention was discontinued. He reported that some extraction and nonextraction cases, expanded during treatment, continued to expand during and after retention. Steadman (1961), somewhat surprisingly, also found that intercanine width changes were unpredictable in their post-treatment stability.

The anterior limits of the lower dental arch is described, not only by the intercuspid width, but also by the incisor position in the sagittal plane. Since the introduction of cephalometrics this position has become a valuable tool when assessing a malocclusion (Broadbent, 1931; Williams, 1969).

The mandibular incisor is believed to be the crux of case analysis (Williams, 1969). Various norms in respect of the position of the lower incisors have been proposed (Steiner, 1953; Tweed, 1954, 1966; Ricketts et al., 1979) and used to predict the stability of treatment results (Williams, 1985).

It is suggested that the lower incisor can only be moved within a small range if stability is to be achieved (Mills, 1966, 1967).

In the maxilla the incisors play an important role as they provide the anterior guiding slope for protrusive excursions of the mandible. The position of the upper incisors should be in harmony with the morphology of the articular eminence in order to protect the temporomandibular joint (Celenza and Nasedkin, 1978; Ash and Ramfjord, 1982). The upper incisor position may be measured relative to the facial axis (Ricketts et al., 1979) or to the Frankfurt horizontal line (Riolo et al., 1974). It's relationship to the lower incisors is described by the interincisal angle (Downs, 1948; Steiner, 1953) as well as by measurement of the overbite and overjet (Moyers et al., 1976; Little, 1975). Although these norms were described for North American Caucasians, they are universally accepted. Specific population studies must be kept in mind when assessing the norms for different ethnic groups (Ricketts et al., 1979; Platou and Zachrisson, 1983).

As a note of caution, however, it should be stated that the abovementioned measurements may be influenced by changes in arch length (Platou and Zachrisson, 1983; Sinclair and Little, 1983). According to Sinclair and Little (1983) dental arch lengths change in untreated normal subjects and recently the same phenomenon was described in orthodontically treated individuals (Little, 1990; Simons and Joondeph, 1973).

Various authors (Gardner and Chaconas, 1976; El-Mangoury, 1979; Udhe, Sadowsky and BeGole, 1983; Little, Wallen and Riedel, 1981) have tried, with little success, to predict whether orthodontically treated dentitions will remain stable (Amott, 1962; Shields, Little and Chapko, 1985; Kaplan, 1988).

8.2 Objectives

The objectives of this part of the present study were:

i) to assess the long-term changes in the parameters defining the anterior limits of the dentition after active orthodontic treatment.

ii) to discuss their possible relationships to lower incisor crowding.

These objectives are encompassed in those of Chapter 7, but the anterior border of the dentition, being such an important area in function and aesthetics, merits a more extensive evaluation and discussion than that presented in Chapter 7.

8.3 Materials and methods

A general description of the materials used and methods employed to analyse the data are set out in Chapter 3.

Orthodontic study casts and lateral cephalograms were analysed for all three stages studied. Intra-observer error was found to be less than 1.0% and it was concluded that this error had no effect on the outcome of the results.

The study casts were measured with digital calipers capable of measuring to 0.01mm. Measurements of the following metrical characters were obtained:

1. The lower intercanine width was measured between the cusp tips (L3-3I) of the clinical crown (Moyers et al., 1976) as well as the most prominent buccal aspect in the mid-longaxis (L3-3B).

2. The arch length measured as the distance from the midpoint between the mandibular central incisors perpendicular to a line joining the mesial aspects of the mandibular lower first molars (ARCHL) (Moyers et al., 1976) as well as the measurement used by Little (LITTLE-A) (Little, Riedel and Engst, 1990).

3. The overjet was measured as the horizontal difference between the buccal surfaces of the mandibular and maxillary central incisors (OJB) (Ricketts et al., 1979).

4. The overbite was measured as the vertical difference between the incisal edges of abovementioned teeth (OBB) (Ricketts et al., 1979).

5. The Little irregularity index (Little, 1975) gave an indication of lower incisor change during the period following active orthodontic treatment.

Cephalometric measurements obtained with the use of the Oliceph computer programme included the following:

1. The mandibular incisor position as described by:
   i) Steiner (1953) (I-NB-MM and I-NB-DEG).
   ii) Ricketts et al. (1979) (I-APO-MM and I-APO-DEG).
   iii) Tweed (1966) (IMPA).
2. The interincisal angle (I-I) (Steiner, 1953).
3. The maxillary central incisor position as described by:
   i) Steiner (1953) (I-NA-MM and I-NA-DEG).
   ii) Ricketts et al. (1979) (I-FACAX).
   iii) Downs (1948) (I/APO-MM).
   iv) Riolo et al. (1974) (I-FH).

The changes in these variables were determined longitudinally with a mean post-treatment follow-up 7 years. They were chosen for their proximity to the anterior limits of the dentition.

The data were subjected to descriptive statistics such as the mean (X) and standard deviation (S.D.) for each of the three evaluations. The Friedman test was used to test for significant longitudinal changes and pairwise comparisons were made if the overall test was significant. Associations between measurements made at the same or different points in time were assessed by Spearman correlation coefficients (r) (Zar, 1984). The significance level of this part of the study was taken to be $p = 0.05$.

8.4 Results

The findings are set out in Tables XXXIV, XXXV, XXXVI and XXXVII.

TABLE XXXIV

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT TO THE ANTERIOR BORDER OF THE DENTITION (Friedman test included)

VARIABLE	T1 MEAN	T1 S.D.	T2 MEAN	T2 S.D.	T3 MEAN	T3 S.D.	p-value	T1-T2 Pairwise Differences	T1-T3 Pairwise Differences	T2-T3 Pairwise Differences
L3-3I	26.19	1.72	25.99	1.69	25.77	1.88	0.08	x	x	x
L3-3B	30.52	1.90	31.07	3.14	30.16	2.11	0.10	x	x	x
LITTLE-A	61.06	4.31	56.69	6.83	54.99	7.05	0.0001	x	+	+
ARCHL	23.50	2.37	20.75	3.19	20.01	3.52	0.0001	+	+	+
I-NB-MM	3.89	2.11	4.32	1.63	4.04	1.65	0.15	x	x	x
I-APO-MM	0.42	2.86	1.29	1.90	0.85	1.93	0.03	-	x	x
IMPA	96.79	10.67	98.54	6.64	97.79	6.68	0.05	-	x	x
I-APO-DEG	23.75	5.17	27.71	4.68	27.38	4.65	0.0001	-	-	x
I-NB-DEG	27.22	6.41	28.43	5.08	26.71	4.72	0.03	x	x	+
I-I	126.40	11.05	127.05	9.34	129.38	7.79	0.03	x	-	x
OJB	6.21	3.29	2.85	0.85	3.17	1.23	0.0001	+	+	x
OBB	4.22	1.48	2.82	0.97	2.81	1.09	0.0001	+	+	x
I-NA-MM	4.14	2.86	2.84	2.61	3.49	2.60	0.002	+	x	-
I/-APO-MM	7.29	3.13	4.31	1.73	4.42	1.93	0.0001	+	+	x
I-NA-DEG	22.99	9.09	22.60	8.44	22.35	7.48	0.83	x	x	x
I/-FH	114.41	8.76	112.55	8.11	112.65	7.09	0.14	x	x	x
I/-FACAX	4.02	8.65	5.57	7.29	6.19	6.08	0.19	x	x	x
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	-

S.D. = Standard deviation
\+ = Significant, $p < 0.05$ (TI > T2, T3)
\- = Significant, $p < 0.05$ (TI < T2, T3)
x = Not significant, $p > 0.05$)

TABLE XXXV

SPEARMAN CORRELATION COEFFICIENTS (r) COMPARING SIMILAR MEASUREMENTS DEPICTING THE ANTERIOR BORDER OF THE DENTITION FOR THE THREE PHASES OF EVALUATION

	T1	T2	T3
VARIABLES	r	r	r
L3-3I and L3-3B :	0.79	0.72	0.69
LITTLE-A and ARCHL :	0.87	0.94	0.91
I-NB-MM and I-APO-MM:	0.74	0.67	0.50
I-NB-MM and IMPA :	0.59	0.42	0.37
I/-FH and I/-FACAX :	-0.87	-0.85	-0.77
I-I and I/-FACAX :	0.82	0.80	0.79

$p < 0.0001$ for all values.

TABLE XXXVI

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIOINSHIP OF THE IRREGULARITY OF THE MANDIBULAR INCISORS AT T3 TO ARCHWITH, ARCHLENGTH AND INCISOR POSITION AT T1, T2 AND T3

L-IRREG

	T1		T2		T3	
VARIABLE	r		r		r	
L3-3I	0.05	0.64	-0.01	0.91	0.16	0.14
L3-3B	-0.01	0.91	-0.06	0.58	0.06	0.58
LITTLE-A	-0.11	0.32	0.06	0.55	-0.01	0.93
ARCHL	-0.12	0.27	0.04	0.72	0.01	0.89
I-NB-MM	-0.07	0.50	0.13	0.23	0.03	0.75
I-APO-MM	-0.19	0.06	-0.03	0.80	-0.07	0.52
IMPA	-0.07	0.49	0.01	0.91	0.05	0.65
I-APO-DEG	-0.20	0.06	-0.04	0.69	-0.05	0.63
I-NB-DEG	-0.16	0.14	-0.08	0.43	-0.06	0.59
I-I	0.06	0.61	-0.02	0.85	-0.09	0.39
OJB	0.20	0.06	0.09	0.43	0.04	0.75
OBB	0.11	0.31	0.13	0.23	0.11	0.29
I-NA-MM	0.04	0.74	0.08	0.45	0.08	0.46
I/-APO-MM	0.08	0.48	0.10	0.34	0.11	0.32
I-NA-DEG	-0.01	0.96	0.07	0.53	0.09	0.42
I/-FH	-0.03	0.79	-0.04	0.71	-0.03	0.79
I/-FACAX	-0.03	0.81	-0.04	0.69	-0.09	0.39

r = Spearman correlation coefficient
Probability values in parentheses, $p > 0.05$.

TABLE XXXVII
LONGITUDINAL COMPARISON OF THE SPEARMAN CORRELATION COEFFICIENTS FOR THE LITTLE IRREGULARITY INDEX (Little, 1975)

	L-IR2	L-IR3
	r	r
L-IR1	0.09 (0.43)	0.03 (0.78)
L-IR2		0.37 (0.0004)

r = Spearman correlation coefficient
Probability values (p) in parentheses.
L-IR = Little Irregularity at T1, T2, T3.

The majority of the measurements (Table XXXIV) remained clinically reasonably stable during the post-orthodontic period (T2-T3). The lower incisor to NB-line measured in degrees (I-NB-DEG), the upper incisor to NA-line measured in millimetres (I-NA-MM) and the Little Irregularity Index changes, although significant, all stayed within acceptable norms (Steiner, 1953; Little, 1975). The only real exception was the arch length change (LITTLE-A and ARCHL) which significantly decreased monotonically from the initial to the final observation (T1-T3).

Some of the groups of variables were correlated with each other in order to assess whether there was a significant agreement between measurements measuring the same parameter. Table XXXV indicates that very strong correlations were indeed achieved. One could thus substitute Little-A for ARCHL or I-NB-MM for I-APO-MM as an example and still make valid conclusions.

None of the correlations in Table XXXVI were of any significance when correlated with the Little Irregularity Index. Regression models were formulated for the dependent variable Little Irregularity (L-IRREG), but this was not succesful. No measured variables could be combined to form a prediction model for the Little Irregularity Index (R-square = 0.01-0.15; C(P) = -0.58-5.69).

The Little Irregularity Index measured at the post-treatment observation (T2) and at the final observation (T3) correlated significantly ($r = 0.37$; $p = 0.0004$) and thus supported the acceptable clinical stability of the treated results (Table XXXIV and XXXVII).

8.5 Discussion

The literature on the stability of the lower arch after orthodontic treatment shows that there is a tendency for the intercanine width to lose the expansion gained during treatment as a result of the canines relapsing toward their initial positions (Pont, 1909; Haas, 1961; Arnold, 1963; Bishara, Chadha and Potter, 1973; Shapiro, 1974; Gardner and Chaconas, 1976). The intercanine width in this sample remained practically unchanged from T1 to T2 (was actually slightly reduced during treatment) ($p > 0.05$) and although it was stable from a clinical point of view when measured at the final observation (T3), there was a tendency to decrease to a value less than the original (T1) dimension (Table XXXIV).

Clinical observation has given some indication of the possibility of achieving a stable expansion of the lower arch subsequent to expansion of the midpalatal suture (Haas, 1965, 1980; Wertz and Dreskin, 1977; Moyers, 1988). It would appear from the data of this study that the lower intercanine dimension ought not to be changed during treatment. The acceptable Little Irregularity Index (Table

XXXIV) probably results from the constant intercanine dimension. The work of Shields, Little and Chapko (1985) would not entirely support this contention.

The lower and upper incisor positions and the interincisal angle which were mensurated cephalometrically, as well as the overbite, the overjet and the Little Irregularity Index recorded on the orthodontic study casts, all changed during the study period (T1 to T3) to within ideal norms (Table XXXIV). Significant changes measured during the post-orthodontic period (T2-T3) were indicated in Table XXXIV. The lower incisor (I-NB-DEG) uprighted 1.72 degrees during this period. Although not highly significant ($p = 0.03$), it can be assumed that its contribution to irregularity took place either as anterior movement beyond stable limits during T1 to T2 or due to the anterior component of force following debanding. This phenomenon could have taken place because the upper incisors and the orbicularis oris and related muscles prevented the lower incisors from staying in a proclined position. The upper incisor (I-NA-MM) proclined 0.65 mm ($p = 0.002$) during T2 to T3. This clinically negligible change could be ascribed to physiological rebound or as part of the changes centering around the lower incisor movement previously noted.

The only significant dimensional change ($p = 0.0001$) which could have influenced the similarly significant change in the Little Irregularity Index ($p = 0.0001$) following active treatment was arch length (LITTLE-A and ARCHL). Arch length continually decreased between T1 and T3. It must be emphasized that although changes took place during T2 to T3 ("relapse") all the end values measured were within acceptable norms. The anterior component of force as well as the mesial drifting tendency of teeth when in occlusion have been cited as reasons for the above phenomenon (Van Beek, 1978). The act of chewing produces a force with a mesial resultant expressed through the contact points of the teeth. The tendency for the teeth to move forward as a result of mastication and swallowing varies greatly according to the angulations of the teeth with each other and is especially affected by the steepness of the occlusal plane (Enlow, 1968; Van Beek, 1978; Behrents, 1984)

Groups of variables measuring practically the same parameter as portayed in Table XXXV showed moderate to strong correlations ($p < 0.0001$).

No significant correlation could be shown in this study for the incisor position, arch length and arch width variables compared with the Little Irregularity Index at T3 (Table XXXVI). This is in accordance with the findings Shields et al. (1985).

It may thus be speculated that for this sample the anterior border of the dentition remained stable following treatment and that the constant reduction in arch length caused the Little Irregularity Index to change from a mean value of 0.43 (T2) to 1.71 (T3). This value of discrepancy is in accordance with a minimum irregularity, 1-3 as described by Little (1975). The lower incisor irregularity at the end of treatment (T2) and the irregularity measured at the final observation (T3) thus remained within clinically acceptable stable limits ($r = 0.37$; $p = 0.0004$) (Table XXXVII). The small change occurring in the Little Irregularity Index could be ascribed to natural changes as was also reported in the literature (Simons and Joondeph, 1973; Sinclair and Little, 1983, 1985).

Sound orthodontic technique will help to attain the ideal treatment goals noted previously and which are imperative to achieve reasonable dental stability. Irrespective of all the meticulous efforts taken by the orthodontists to secure a functional and stable occlusion, certain changes do occur. Some may call it relapse, others settling or physiological rebound. The crux of the matter is that orthodontists have to accept that natural changes will occur following treatment and as long as there is a sound periodontium this will be the order of the day. Patients must be made aware of this fact and that, with slight irregularity, enamel approximation may be required to help solve the problem (Sheridan, 1987; Radlanski and Jager, 1988; Sheridan and Ledoux, 1989; Joseph and Rossouw, 1991). The orthodontist cannot be held responsible for natural changes which might influence an ideal treatment result. Patient education or informed consent relating to these changes cannot be overemphasized.

8.6 Conclusions

1. Ideal treatment goals are essential if acceptable

stability of orthodontic treatment is to be achieved.

2. Variables describing similar dimensions or positions impart similar information and all or only one can be used to evaluate the relevant recordings.

3. Expansion of the mandibular arch beyond the original intercanine dimension is likely to lead to failure as this dimension tends to decrease to below the original measurement in the long-term.

4. Change in arch length appears to be a major cause of mandibular incisor irregularity.

CHAPTER 9

A LONGITUDINAL EVALUATION OF THE VERTICAL DIMENSION OF THE CRANIOFACIAL SKELETON IN SUBJECTS FOLLOWING ORTHODONTIC TREATMENT AND ITS RELATIONSHIP TO POST-ORTHODONTIC LOWER INCISOR CROWDING

9.1 Introduction

The vertical relationship of the craniofacial skeleton of orthodontic subjects can be assessed using cephalometric analyses and photographic analyses. Originally the focus of cephalometric analysis was on anteroposterior dimensions as these measurements could be related to the Angle classification of malocclusion (Angle, 1899, 1907). A committee of the British Orthodontic Society suggested that although the Angle system was an adequate classification of anteroposterior jaw relationships, it did not include information about the transverse and vertical planes of the face and should be extended to do so (Bennett, 1912). It is important to distinguish between dental and skeletal components when measurements in the vertical plane are evaluated.

The overbite or bite depth is determined by the contact relationships of the teeth. This causes an inherent contradiction in terms such as "skeletal open bite" and "skeletal deep bite". The work of Sassouni (1970) defined these terms as indicating skeletal proportions that cause a built-in tendency toward deep bite or open bite relationships. As the mandible rotates downwards, there is an increasing tendency towards an anterior open bite. Conversely, a closing or upward rotation of the mandible results in a tendency towards a deep bite. The chin is also influenced by the mandibular rotations. A closing or forward rotation results in a prominent chin button and a backward or open rotation leads to a relatively weaker or more distally positioned chin (Graber and Swain, 1985).

Various methods may be used to assess the vertical relationships of the facial skeleton (Downs, 1948; Steiner, 1953; Tweed, 1954; Coben, 1955; Moorrees and Lebret, 1962; Bell, Proffit and White, 1980; Ricketts, 1981; McNamara, 1983; Moyers, 1988). The Björk facial polygons emphasize the interaction between facial and cranial base factors and demonstrate how variations in, for example the cranial base flexure angle, can influence the mandibular plane angle or anterior vertical facial dimensions (Jarabak and fizzell, 1972).

Vertical dental problems are normally associated with the type of skeletal pattern which is present. The amount and direction of mandibular rotation strongly influences posterior dental eruption, which tends to be deficient in skeletal deep bite facial patterns and excessive in skeletal open bite facial types. Dental compensation for the skeletal jaw relationships can occur in the amount and direction of eruption of the anterior teeth (Graber and Swain, 1985).

Norms for infra-eruption and supra-eruption were published as linear measurements from the base of the alveolar process (Riolo et al., 1974). A critical distinction, however, must be made in diagnosis of vertical problems. A skeletal problem is not necessarily accompanied by a dental problem, suggesting that for example, a skeletal open bite may or may not be accompanied by a dental open bite (Graber and Swain, 1985). It is obvious that the treatment prescribed for a Class II deep bite dental relationship would be different from that prescribed for a Class II skeletal deep bite pattern.

The aetiological factors which may cause vertical problems have been well documented ranging from simple thumb sucking habits, ankylosis, upper airway obstruction to genetic inheritance (Proffit, 1986; Moyers, 1988).

The success of non-surgical (only employing orthodontic treatment) correction of vertical problems is normally measured by the stability of the overbite-overjet relationship.

Overbite correction and stability have been subjects of a great deal of controversy (Fogel and Magill, 1970). Concerning these subjects Schudy (1963) states that, "when molars are moved occlusally during treatment, overbite correction is nearly always successful". The intrusion of incisors, he claims, will result in re-extrusion, causing a return of the overbite, and he advises against the intrusion of mandibular incisors. This concept is in direct contrast to the advised use of the utility arch (Ricketts *et al.*, 1979). They stated that when molars were extruded or moved occlusally, the masticatory muscles in reverting to their previous origin and insertion lengths will re-establish overbite and facial height. They further believe that incisor intrusion also provides a greater likelihood of stability in overbite reduction than does molar extrusion. This is due to the fact that the freeway space is preserved when vertical problems are treated by incisor movements.

The modality and effectiveness of bite plate therapy has also been a subject of debate. Mershon (1937) stated that "elongation of the posterior teeth throws a constant strain on the muscles of mastication, and destroys the interrelated harmony of parts". He observed that the only permanent change resulting from bite plate therapy was the depression of anterior teeth in the alveoli. In contrast it was reported that the correction of a deep overbite through the use of a bite plate was permanent, and encouraged further eruption of the posterior teeth (Hemley, 1953). The latter author claimed that there was no depression of mandibular incisors as the result of the use of a bite plane.

The Begg orthodontic treatment philosophy encourages that bite opening should be accomplished by intrusion of upper and lower incisor teeth, and that molar height should be relatively undisturbed (Begg, 1971, 1977). Dr. Begg felt that extrusion of molar teeth invited overbite relapse.

In a study regarding intrusion of teeth Swain and Ackerman (1969) found that anterior overbite correction was accomplished mainly through an increased eruption of the mandibular molars, and not by an intrusion of the mandibular incisors; and that in almost all cases examined, mandibular molars continued to erupt after appliance removal. During treatment, maxillary molars and incisors did not exhibit the same degree of eruption as did their mandibular counterparts. They pointed out that this observation may be due to the fact that the palatal plane is not as reliable as the mandibular plane for superimposition when assessing total vertical growth.

There is some evidence to show that mandibular molars do not intrude during retention, but actually continue to erupt as do the mandibular incisors. During the retention period, the maxillary molars and incisors remain at the same vertical level, or tend to erupt to a lesser degree than do their mandibular counterparts (Fogel and Magill, 1970).

Dental extractions perfomed as part of orthodontic treatment should not cause an increase in the overbite if adequate care is taken by the operator. Deep overbite per se, before treatment, is thus not necessarily a contraindication for extraction therapy (Magill, 1960). Orthodontists, should in such patients refrain from using any force, which would tip the occlusal plane upward in the incisor area. Continued use of Class II elastics is advocated in these instances (Schudy, 1964).

The measurement of the interincisal angle forms an important part of many cephalometric analyses. The interincisal angle is concerned with the stability of the overbite. Norms for the interincisal angle were proposed, amongst others, by Steiner (1953). He favours a labial axial inclination of the maxillary and mandibular incisors with an ideal interincisal angle of about 131 degrees. Schudy (1963) prefers a more obtuse interincisal angle of 135 degrees. Ricketts et al. (1979) on the other hand advocate a more acute interincisal angle, suggesting a value of 125 degrees as an acceptable norm.

The greater the closing rotational growth within the mandible, the greater will be the compensatory proclination necessary to keep the incisors within the area of balance (Perera, 1987). On the one hand downwardly-directed mandibular growth and/or treatment change and on the other hand forward mandibular rotations are among the factors which may contribute to late crowding of the anterior part of the lower arch (Björk and Skieller, 1972; Richardson, 1986). Orthodontists should refrain from creating an open rotation of the average mandibular plane angle during treatment as this angle tends to become more acute during maturation of the face (Tweed, 1954, 1966). This phenomenon will cause lower incisor irregularity in a similar way as that caused by the normal forward closing rotation of the mandible during post-treatment growth (Björk and Skieller, 1972). Apart from the above two growth patterns no correlation could, however, be shown between lower incisor relapse and other skeletal and dental parameters (Shields, Little and Chapko, 1985; Little, 1990).

9.2 Objectives

There was no longitudinal data available for this sample (Table I) in respect to growth or orthodontic treatment changes. It was thus important to study the vertical dimension, which was not previously defined in this manner, with the purpose to add new data to the literature, and to enable one to compare the changes occurring in this sample to the studies noted previously.

Hence, the objectives of this part of the study were:

i) to assess the longitudinal changes in the vertical dimensions of subjects following orthodontic treatment.

ii) to determine if any correlation existed between the vertical changes observed and post-orthodontic lower incisor crowding.

9.3 Materials and methods

Eighty-eight Caucasian subjects were longitudinally assessed in respect of relapse of their dentitions following orthodontic treatment. The malocclusions were treated using conventional edgewise mechanics. A general description of the materials used and the methods employed to assess the data is given in Chapter 3. A description of the sample is set out in Table I.

Orthodontic study casts and lateral cephalograms were analysed for all three of the stages studied. Intra-observer error for this part of the study was found to be less than 1.0% and it was concluded that this error had no significant effect on the outcome of the results.

The study casts were measured with digital calipers capable of measuring to 0.01mm. The following variables were measured:

1. The Little Irregularity Index (L-IRREG) as described by Little (1975).

2. Overbite (OBB) (Ricketts et al., 1979; Moyers, 1988).

The cephalometric measurements selected to depict the vertical facial development were the following:

1. The mandibular plane angle GOGN-SN (Steiner, 1953) and FMA (Tweed, 1954; Ricketts, 1981).

2. The facial axis angle (FAC-AXIS), mandibular arc (MAND-ARC) and lower facial height (L-FACH) as described by Ricketts (1981). These variables together with the FMA determine the chin position relative to the rest of the face.

3. The Björk/Jarabak cephalometric analysis (Jarabak and Fizzell, 1972) describes the rotational pattern of the face. Amongst other variables it also describes an anterior deep bite tendency as contributing to a closing rotation of the mandible. Mensuration of vertical dimensions by Björk/Jarabak (Jarabak and Fizzell, 1972) were:

i) Anterior facial height measured from Nasion to Menton (ANTFACH-MM).

ii) Posterior facial height measured from Sella to Gonion (POSTFACH-MM).

iii) The posterior to anterior facial height ratio expressed as a percentage (SGO-NME). Open rotation (smaller than 62%) or closing rotation (larger than 65%) could be predicted.

iv) The articular angle measured from Sella to Articulare to Gonion (ARTANGLE).

v) The Gonial angle measured from Articulare to Gonion to Menton (GONANGLE).

vi) The sum angle (SUMANGLE) is a summation of (iv), (v) and the cranial base angle measured from Nasion to Sella to Articulare (SADANGLE). The sum angle gives an indication of a clockwise (the value of the summation of the three angles is larger than 396 degrees) or counterclockwise (the value of the summation of the three angles is less than 396 degrees) rotational facial pattern.

vii) The ramus height measured as the distance between Articulare and Gonion (RAMH-MM). Counterclockwise or closing rotation of the mandible indicates a more rapidly increasing posterior face height. The ramus height dimension assisted in this regard.

4. The interincisal angle (I-I) as described by Steiner (1953).

The data were subjected to descriptive statistics such as mean and standard deviation for each of the three sets of records studied. The Friedman test was used to test for significant differences between the groups at the three time intervals. Spearman correlation coefficients were used to study the relationships of the different variables to the post-orthodontic lower incisor irregularity (T3) (Little, 1975) (Zar, 1984). The accepted significance level of this part of the study was taken to be $p = 0.05$.

9.4 Results

The findings of this study are set out in Tables XXXVIII and XXXIX.

The purpose of the measurements in this part of the study was to assess the longitudinal changes which took place in the vertical relationship between the maxilla and the mandible (Table XXXVIII). These changes were subsequently correlated with the post-orthodontic Little Irregularity Index (Little, 1975) (Table XXXIX).

Significant mean changes of variables ($p < 0.05$) that were measured during active treatment (T1-T2) were: an open rotation (increase of the angle) of the FAC-AXIS by an average of 0.58 degrees, a mean increase in the L-FACH of 1.06 degrees, mean increases in the ANTFACH-MM of 6.74 mm and POSFACH-MM of 4.45 mm, a mean increase in the RAMH-MM of 3.18 mm and a mean decrease in the L-IRREG of 3.81 mm and in OBB of 1.40 mm (Table XXXVIII).

TABLE XXXVIII

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT TO THE VERTICAL DIMENSION
(Friedman test included)

	T1		T2		T3			T1-T2	T1-T3	T2-T3
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	p-value	Pairwise	Differences	
GOGN-SN	33.44	4.93	34.05	5.76	32.19	6.24	0.0001	x	+	+
FMA	23.09	4.69	23.39	5.52	21.46	7.11	0.0001	x	+	+
FAC-AXIS	88.94	4.11	88.36	4.46	89.43	5.13	0.0001	+	x	-
MAND-ARC	29.91	5.47	30.76	5.95	33.90	5.91	0.0001	x	-	-
L-FACH	43.56	4.44	44.62	4.83	44.03	5.01	0.0001	-	x	+
ANTFACH-MM	115.91	5.94	122.65	7.34	126.49	7.90	0.0001	-	-	-
POSTFACH-MM	74.44	4.89	78.89	6.27	85.01	7.98	0.0001	-	-	-
SGO-NME	64.32	4.39	64.50	4.93	67.25	5.17	0.0001	x	-	-
ARTANGLE	146.11	7.11	146.08	7.43	146.10	7.62	0.58	x	x	x
GONANGLE	124.31	6.34	124.44	6.54	121.83	6.81	0.0001	x	+	+
SUMANGLE	393.89	5.38	394.46	5.98	391.78	6.36	0.0001	x	+	+
RAMH-MM	42.94	4.16	46.12	5.25	51.49	6.82	0.0001	-	-	-
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	-
OBB	4.22	1.48	2.82	0.97	2.81	1.09	0.0001	+	+	x
I-I	126.40	11.05	127.05	9.34	129.38	7.79	0.03	x	-	x

S.D. = Standard deviation
\+ = Significant, $p < 0.05$ (T1 > T2, T3)
\- = Significant, $p < 0.05$ (TI < T2, T3)
x = Not significant, $p > 0.05$

TABLE XXXIX

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE IRREGULARITY OF THE MANDIBULAR INCISORS AT T3 TO THE VARIABLES DEPICTING THE VERTICAL DIMENSION AT T1, T2 AND T3

	L-IRREG					
	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
GOGN-SN	0.04	0.73	0.04	0.74	0.008	0.94
FMA	0.01	0.89	0.08	0.46	0.02	0.89
FAC-AXIS	-0.09	0.39	-0.07	0.50	-0.10	0.35
MAND-ARC	-0.05	0.66	-0.16	0.14	0.05	0.63
L-FACH	0.13	0.23	0.06	0.59	0.10	0.34
ANTFACH-MM	0.001	0.99	-0.02	0.84	0.17	0.12
POSTFACH-MM	-0.03	0.81	-0.07	0.53	0.02	0.87
SGO-NME	-0.04	0.74	-0.05	0.62	-0.06	0.60
ARTANGLE	-0.02	0.82	-0.04	0.69	0.01	0.91
GONANGLE	0.04	0.73	0.08	0.46	0.04	0.71
SUMANGLE	0.06	0.61	0.05	0.63	0.06	0.59
RAMH-MM	-0.07	0.54	-0.18	0.09	-0.01	0.89
OBB	0.11	0.31	0.13	0.23	0.11	0.29
I-I	0.05	0.61	-0.02	0.85	-0.09	0.39

r = Spearman Correlation Coefficient
p = Significance level, $p < 0.05$

Significant mean changes (p < 0.05) which occurred during the post-orthodontic assessment period (T2-T3) were decreases in the GOGN-SN (1.86 degrees), FMA (1.93 degrees), L-FACH (0.59 degrees), GONANGLE (2.61 degrees) and SUMANGLE (2.68 degrees), and increases in the FAC-AXIS (1.07 degrees), MAND-ARC (3.14 degrees), ANTFACH-MM (3.84 mm), POSFACH-MM (6.12 mm), RAMH-MM (5.37 mm) and L-IRREG (1.28 mm) (Table XXXVIII).

The anterior and posterior facial and ramus heights were the only metrical variables which showed significant changes (p = 0.0001) at all three of the intervals assessed being pre-treatment to end of active treatment (T1-T2), pre-treatment to the final observation at the end of the study (T1-T3) and post-treatment to the end of the study (T2-T3) (Table XXXVIII).

No significant correlations (r < 0.18, p > 0.05) were observed between the variables studied in this part of the project and post-orthodontic lower incisor irregularity (Table XXXIX).

9.5 <u>Discussion</u>

The subject of post-orthodontic treatment failure is as wide as the field of orthodontics itself (King, 1974).

The general morphology of the face and its various parts largely determines the direction of growth of these parts. Orthodontists are well aware that growth can account for the success or failure of a treated malocclusion (Brodie, 1941, 1953), Björk (1947), Lande (1952), (Richardson (1986) and Perera (1987).

Growth may also cancel out some of the unfavourable side effects resulting from orthodontic appliances. For example, in any type of malocclusion the simple placement of an orthodontic appliance causes the teeth to extrude sligthly from the alveolar processes. Leveling teeth in most types of Class II treatment tends to cause further dental extrusion. In nongrowing patients the nett effect of the dental extrusion is to cause the mandible to tip downwards and for Pogonion to move posteriorly. With active growth, however, the unfavourable side effects of the orthodontic appliances apparently did more or less what growth would have done and the mandible usually recovered its original position (King, 1960, 1974). When this phenomenon of downward tipping of the mandible occurred in the absence of growth, the subsequent recovery after treatment contributed to some of the unfavourable sequelae of orthodontic treatment.

The mandibular plane relationship to the cranial base (GOGN-SN and FMA) did not change significantly during treatment. An opening rotation of the mandible was, however, observed during this time (T1-T2), borne out by significant mean changes in the variables GOGN-SN, FMA and FAC-AXIS. The slight jaw opening could have been due to the treatment mechanics. MAND-ARC, SGO-NME and RAMH-MM showed favourable counterclockwise rotation of the mandible.

The general picture of the facial changes observed (T1-T3), is in accordance with the changes expected in normal patients without treatment (Riolo et al., 1974; Moyers et al., 1976; Ricketts, 1981; Sinclair and Little, 1983, 1985). The general increase in facial dimensions, as a result of growth, was also manifested in the anterior and posterior facial heights.

Following on orthodontic treatment mean vertical dental corrections were achieved as a result of the overbite being significantly ($p = 0.0001$) reduced from 4.22 mm - 2.82 mm during active treatment (T1-T2). The interincisal angle was slightly increased but remained within acceptable means for normal individuals and this change was not significant ($p > 0.05$) from T1 to T2. The achievement of a low mean value of 0.42 mm for the Little Irregularity Index (1975) at T2 indicated successful alignment of the lower incisors (Table XXXVIII).

The forward closing rotation (counterclockwise) of the mandible continued in the post-orthodontic period (T2-T3). This was observed in all the variables describing this phenomenum (Table XXXVIII). Only the ARTANGLE showed no significant change during this period. The average changes occurring during this period were mainly due to growth. Following the removal of appliances some rebound of areas, containing elastic tissues, could also have taken place, especially if those areas were changed during treatment and should have been kept unaltered. When assessing the changes during the period T1 to T2 it may be noted that clinically acceptable norms were maintained and that many of the changes could be ascribed to normal growth changes.

Overbite changes recorded in this study were not consistent with others reported in the literature which reported that overbite decreased during treatment and had a tendency to increase sligthly after treatment (Dona, 1952; Walter, 1953; Stackler, 1958; Magill, 1960; Rose, 1967; Hernandez, 1969; Bishara, Chada and Potter, 1973; Simons and Joondeph, 1973; El-Mangoury, 1979; Uhde, Sadowsky and BeGole, 1983). It has been suggested by some authors that deep overbite situations should be overtreated in anticipation of relapse which tends to occur during the post-treatment period (Riedel, 1960, 1969; Ludwig, 1966; Smith, 1969). Bresonis and Grewe (1974) reported that post-treatment overbite increased the least in Class I and Class III cases, and the most in Class II division 1 cases. In constrast Hechter (1975) maintained that Class II division 2 and not Class II division 1 malocclusions experienced the greatest overbite increase after treatment. The mean post-orthodontic follow-up period for the present study was 7 years (mean post-retention period 5 years). The overbite remained practically unchanged during this period (T2-T3). The mean interincisal angle (Table XXXVIII) responsible for maintaining the overbite was less than 130 degrees and the incisor positions on their apical bases were also within norms (Table XXXIV, Chapter 8). Excellent orthodontic technique or too short a post-orthodontic follow-up period could be the reason that there was so little change in the incisor region (T2-T3) in the present sample. Another possible cause for this result could be the fact that all the Angle dental malocclusions were studied as a mixed group. Some of the other samples previously cited included only one of Angle's classifications. There exists, however, variability between the dental classification (Angle, 1899) and the skeletal classification (Steiner, 1953) which makes this observation doubtful (Table 0). The discrepancy between the dental and skeletal classification lead to the decision to study the malocclusions as a group.

Irregularity of the lower incisors was experienced at T3, but never to the same extent as the recorded pre-treatment crowding. This is in agreement with the results of Uhde, Sadowsky and BeGole (1983). The mean changes in the Little Irregularity Index (Little, 1975) from T2 to T3, however, were within clinical acceptable limits. The changes which occurred appeared to be associated with a mandibular forward rotation, although no significant correlation could be found to support this observation (Table XXXIX). The literature reports similar findings (Richardson, 1986; Perera, 1987). The application of sound treatment principles could assist in preventing severe relapse in the incisor region. Patients and parents, however, should be informed that changes in the vertical dimension of the dentofacial environment may take place in the post-treatment period and that these could influence the alignment of teeth detrimentally.

9.6 Conclusions

1. A mean mandibular forward rotation was noted throughout the study (T1-T3) which corresponds to the changes occurring during normal growth.
2. Growth appeared to be responsible for most of the post-treatment changes.
3. Overbite tended to remain stable following orthodontic treatment which is in contrast to overbite changes occurring during normal growth and to that recorded in some studies noted.
4. A slight increase in lower incisor irregularity could have been caused as a result of mandibular growth changes.

CHAPTER 10

LONGITUDINAL EVALUATION OF EXTRACTION VERSUS NONEXTRACTION TREATMENT WITH SPECIAL REFERENCE TO THE POST-TREATMENT IRREGULARITY OF THE LOWER INCISORS

10.1 Introduction

It is much easier to extract teeth than to determine with certainty whether it is absolutely necessary to do so. The extraction of a tooth requires nothing more on the part of the practitioner than some skill in the use of the instruments which are usually employed in this operation: whilst the knowledge nescessary to appreciate the long-term consequences of dental extractions can only be acquired by time and study (Delabarre, 1815).

Extraction of teeth as an aid in the treatment of malocclusion is one of the oldest and most controversial subjects in the history of orthodontics. During the early 1900's the controversy reached its peak with Edward H. Angle and Calvin S. Case representing opposite viewpoints in this matter (Cole, 1948).

Angle's dictum of a full complement of teeth was: that the loss of two, four or even eight premolars arrested facial development and expression and was far more damaging to the patient's future than were crowded anterior teeth. According to Angle, extraction procedures never overcame faulty muscular function (Weinberger, 1950) and accordingly orthodontic treatment should set out to remove the causes of malocclusion while retaining a full compliment of teeth (Angle, 1907). Angle's influence dominated the discipline of orthodontics for many years. With the development of gnathostatic evaluation of dental occlusions, as well as the simultaneous introduction of cephalometrics by Broadbent (1931) and Hofrath (1931), the limitations of a dominant nonextraction philosophy could be assessed.

The extraction controversy gained momentum with Case in the 1920's (Case, 1964) promoting extractions in orthodontic treatment. Many others also played a significant role in resisting Angle's demand that the teeth should be kept in place despite the type of malocclusion being treated (Tweed, 1946; Nance, 1947; Dewel, 1959). Tweed (1946) maintained that the dentition remained relatively stable once it reached that state in the development of a malocclusion in which the forces, originally responsible for initiating the malocclusion, became neutralized. An irregular dentition which is in balance may therefore present a far more stable condition than does that same dentition after orthodontic treatment. This is particularly so if the treatment forces the the teeth into a protrusive relationship to the supporting portion of the bony base. This form of orthodontic treatment tends to be followed by the "collapse" of the dental arches which in a normal occlusion is in harmony with its skeletal apical bases. A large percentage of malocclusions, which orthodontists are called upon to treat, have deficient and/or deformed apical bases (Howes, 1947). Begg (1954) supported extractions in orthodontic treatment after having studied stone-age man's dentition. As a result of his studies he attributed good alignment of teeth to interproximal attrition as a result of coarse diets and subsequently advocated extractions as a means of compensating for the lack of attrition in most modern dentitions. Tweed (1944), one of Angle's most ardent supporters, was so discouraged by post-retention relapse that he seriously considered giving up his profession as an orthodontist. He examined 70 percent of the patients whom he had treated during six and a half years of orthodontic practice during which he followed Angle's philosophy which demanded a full complement of teeth. To his amazement he found that only 20 percent of the cases which he reviewed still met his original orthodontic objectives, which were:

i) A stable end result - teeth that remain in their corrected positions.
ii) Healthy investing tissues to insure longevity of the denture.
iii) A dental apparatus which works efficiently.
iv) The best facial aesthetics.

Following this humbling experience, Tweed displayed great courage when he subsequently treated similar bimaxillary protrusion cases, half by "conventional" nonextraction treatment and half by the removal of four first premolars. In the first group he reported a labial displacement of the mandibular incisors from their normal positions and a resultant collapse of these incisors. In the second group, where four premolars had been extracted and the mandibular incisors correctly positioned in relation to their supporting basal bone, the subjects remained free from serious relapse following one year of retention. Retreatment of those patients, who ended up in bimaxillary protrusion, by removal of four premolars resulted in greater stability several years post-retention. A study which included 100 extraction, and 100 nonextraction subjects, was examined 25 years post-retention (Tweed, 1968). While not based on scientific facts, Tweed concluded that the extraction cases were more stable than were the non-extraction cases. Glenn, Sinclair and Alexander (1987) studied 28 nonextraction cases which were an average of eight years out of retention. In these patients, which were treated by the same orthodontist, they found that slight incisor irregularity occurred post-retention. Relapse patterns were similar to but more severe than, those seen in a study conducted in an untreated normal population (Sinclair and Little, 1983). The changes in the normal population were only one half as severe as those observed in studies performed by Little et al. (1981, 1988). According to Little et al. lower incisors, when measured to the APo line, were proclined an average of 1.4 mm during treatment, tended to remain stable post-retention. Sandusky (1983) reported on the post-retention stability of 83 extraction cases treated by Tweed and Tweed foundation members. Using Little's Irregularity Index (Little, 1975) to grade the results he found less than ten percent relapse of the lower incisors. Similar results showing that lower incisors maintained better alignment following orthodontic treatment were reported by Davies (1971) and Kuftinec (1975). In a sample consisting of 45 nonextraction and 27 extraction cases Uhde, Sadowsky and BeGole (1983) showed a greater degree of crowding at the beginning of treatment, and less relapse 20 years post-retention in the extraction group than did the non-extraction group of patients.

The presence of mandibular incisor crowding indicates that there is a space shortage somewhere in the dental arches. The incisor position (Downs, 1948; Steiner, 1953; Tweed, 1954; Ricketts, 1981) and facial profile (Holdaway, 1983), in combination with a tooth-arch size analysis, provide clues which can help to make a decision whether an extraction or nonextraction treatment regime must be followed. Mandibular incisors should, as is found in normal individuals, always be positioned upright over the medullary bone of the jaw (Tweed, 1946). Relapse of dentitions following orthodontic treatment may be influenced by apical base differences, the subject's age, the period of retention, incisor positions relative to basal bone, post-treatment growth, third molar development, periodontal fibres, habits, occlusal functioning, Bolton discrepancies, continued decrease in arch length and other unknown factors (Little, Wallen and Riedel, 1981). Richardson (1980, 1981) summarised a number of possible aetiologic factors which cause mandibular arch crowding.

Following a nonextraction philosophy in the belief that a particular orthodontic appliance will enhance bone growth could lead to a great deal of disappointment. It is probably impossible to induce meaningful growth in tooth-bearing bones by means of orthodontic appliances (Brodie, 1940a). Brodie (1940b) also demonstrated that once the growth pattern of the facial bones is established, whether normal or abnormal, it is virtually constant and resistant to change. Natural expansion does, however, occur as a result of normal growth and development (Friel, 1927). It would be incorrect to assume that those appliances used during this growth period were the cause of the expansion. The area of the alveolar arch correlates closely with the area of the dental arch (Richardson and Brodie, 1964). A cephalometric study which evaluated relapse in Class II division 1 subjects who where treated without extraction of teeth, with either the Andresen activator or the Bionator, showed considerable individual variation in relapse of overjet (age and Hunt, 1990). Using the results of a number of cephalometric studies dealing with the treatment effects of functional appliances on Class II division 1 malocclusions, it was concluded that overjet reduction occurred predominantly as a result of dento-alveolar changes (Mills, 1983). Dento-alveolar changes also appear to be largely responsible for overjet relapse especially when incisors are proclined during treatment (Wieslander and Lagerstrom, 1979; Clavert, 1982; Hunt and Ellisdon, 1985). Antero-posterior and/or lateral increase in the mandibular arch form usually fails with the dental arch typically returning to the pre-treatment size and shape (Little, 1990). Malocclusions treated by means of rapid maxillary expansion, however, have been shown to stay stable 8 years post-treatment (Haas, 1980). Haas maintains that his success can be ascribed to a combination of his method of treatment (rapid maxillary expansion) and to the duration of the retention which he uses.

Subjects treated without extraction by means of Bimler appliances showed a greater degree of upper lip flattening as a result of a stretching of the lips. This stretching apparently results from an increase which occurs in anterior facial height. Patients in whom extractions were performed seemed to maintain more aesthetic lip morphology (Stromboni, 1979). The health of the temporomandibular joint as well as the convexity of the facial profile have been used to justify both extraction and nonextraction philosophies. Conlin (1989) recalled 1000 subjects and evaluated their long-term dental stability and facial aesthetics. He found that there is no real need for extraction cases to appear flat or for nonextraction cases to appear full.

One of the greatest challenges in orthodontics is the need to make a sound diagnosis. No cookbook recipe is available in respect of extraction or nonextraction treatment. Various strategies are used to aid orthodontists in their extraction decisions including the use of visual treatment objectives (Ricketts et al., 1979; Holdaway, 1984). Clinical experience gradually allows each orthodontist to develop an own philosophy (De Castro, 1974).

The frequency of extractions vary greatly among orthodontists. A study in the northwestern USA revealed that the average prevalence is about 42.1% (Peck and Peck, 1979). Another study found the range to vary between 5 and 87% with the average being 39% (Weintaub et al., 1989).

Ethnic and socio-economic differences will obviously influence the prevalency of the extractions performed by orthodontists. Japanese and Chinese orthodontists treat many bimaxillary protrusions in conjunction with extractions, whereas government clinics in eastern Europe favour nonextration treatment. The National Health scheme in England also appears to have tilted the scale in favour of extractions in orthodontics (Peck and Peck, 1979).

Extraction, as an only option, regulary complicates a treatment regime. Problems which dictate one or other form of extraction, which is not within the control of the orthodontist, include: caries, periodontitis, endodontic problems or even some development defect. Extraction treatment on average was found to consume more time to complete than does nonextraction treatment (Vig et al., 1990).

The ultimate decision as to whether extractions should be performed as part of the orthodontic treatment may depend on how well the patient co-operates. Anchorage control plays an important part in allowing the clinician to achieve the planned-for goals. Anchorage, a term used loosely in orthodontics, may be derived from various sources, including root surfaces, cortical bone or even extra-oral appliances (headgear) (Ricketts et al., 1979; Moyers, 1988). Dental implants used to augment anchorage are a recent development (Roberts, Marshall and Mozsary, 1990). The conventional Begg technique uses differential anchorage (Storey and Smith, 1952) and not extra-oral traction to preserve anchorage when retracting the anterior segment of teeth (Williams and Hosila, 1976). Williams and Hosila (1976) noted additional advantages to performing extractions. Extractions tend to reduce the mandibular plane angle (FMA) between 1.2 to 1.8 degrees during treatment and the chances of the third molars erupting, improve from 52.5% (first premolar extractions) to 90% (first molars extractions). The latter observation, however, cannot be taken for granted as it was shown that the impaction of third molars need not necessarily be avoided by extracting premolar teeth (Faubian, 1968; Richardson, 1989). Molar extraction, however, will in most instances eliminate third molar impaction (Richardson, 1974). Late lower arch crowding may on occassion be prevented by relieving the eruptive pressure from third molars by extracting the lower second molars (Richardson and Mills, 1990).

In orthodontics a variety of teeth may be extracted. These include: mandibular incisors (Bahreman, 1977; Kokich and Shapiro, 1984), maxillary canines (Jacoby, 1983), premolars (Hotz, 1970; Graber, 1971; Gianelly and Valentini, 1973; Dewel, 1976; Joondeph and Riedel, 1976; Ingram, 1976; Ketterhagen, 1979), first molars

(Daugaard-Jensen, 1973; Williams, 1979), second molars (Liddle, 1977; Richardson and Mills, 1990) and third molars (Chipman, 1961; Ricketts et al., 1979; Richardson, 1987).

Dental changes, including the common occurance of lower incisor crowding, many years after successful orthodontic treatment, may signify failure in orthodontics. Hence the need to distinguish between operator error and normal growth changes (Hellman, 1944). The extraction of four premolar teeth has been recommended to limit incisor crowding following orthodontic treatment (Hellman, 1943; Proffit, 1986). Proffit (1986) believes that an additional benefit of extraction therapy lies in the better lip contours which are usually obtained. There is no complete agreement in respect of the latter observations. It has been reported that irrespective of whether individuals were treated with or without extractions, relapse of overbite (Simons and Joondeph, 1973) as well as relapse of lower incisor alignment still occurs following the removal of the appliances (Little, Wallen and Riedel, 1981). Only about 30% of occlusions treated with first premolar extraction therapy retain good anterior mandibular alignment while two thirds of the sample relapse (Little, Wallen and Riedel, 1981). In comparing the results of a sample showing minimal incisor relapse (Sandusky, 1983) with a sample showing about two thirds relapse (Little, Wallen and Riedel, 1981) it was concluded that the orthodontic technique utilised plays an important role in achieving stability of the post-treatment orthodontic result (Gorman, 1990).

In an attempt to search for associations between long-term skeletal and dental change, a cephalometric appraisal was performed on first-premolar-extraction subjects (Shields, Little and Chapko, 1985). The post-treatment and post-retention incisor positions as well as amount or direction of facial growth, were found to be poor predictors of long-term mandibular incisor irregularity. Other studies also failed to demonstrate any correlation between pre-treatment and post-treatment lower incisor alignment in first, (Little, Wallen and Riedel, 1981) and second premolar extractions (McReynolds and Little, 1991). Statistically significant differences in their cephalometric measurements existed between minimally, and moderately to severe crowding groups in the post-retention period of subjects treated with second premolar extractions (McReynolds and Little, 1991). Nonextraction treatment regimes have also provided information in respect of post-orthodontic stability (Shapiro, 1974; Gallerano, 1976; Glenn, Sinclair and Alexander, 1987). The lesser degree of initial crowding in the nonextraction groups tend to bias such studies and a direct comparison of extraction, and nonextraction samples must therefore be made with caution (McReynolds and Little, 1991).

Teeth which are moved together orthodontically following extraction of an adjacent tooth do not move through the gingival tissue, but appear to push the gingivae in front of it into a fold of epithelial and connective tissue. This excess tissue can result in the opening of the extraction space which constitutes a common form of relapse of orthodontically treated occlusions. By surgically removing this tissue, relapse could be alleviated (Edwards, 1971).

Enlow (1980) defined relapse as "a histogenetic and morphogenic response to some anatomical and functional violation of an existing state of anatomic and functional balance." Relapse is usually thought of as a "rebound" movement in which teeth recoil back somewhere close to their original positions once the retentive forces are removed. Enlow does not accept the idea that the relapse process is merely a passive mechanical recoil reaction of the periodontal membrane to stresses placed on it's fibres. He stated that periodontal fibres have a great capacity for remodeling and can accomodate to virtually any tooth position if a regional state of anatomic and physiologic balance exists. Early writings stressed the importance of placing the teeth in excellent occlusion and holding them there until the perioral musculature adapts to the new position (Barnes, 1956). Lower incisor crowding which develops post-retention has been attributed to a failure of the muscles to adapt.

Mershon (1936) stated that the final position of the teeth was like "an argument with Mother Nature" who always won. Post-retention stability, one of the major problems facing orthodontists, was well defined by Hawley (1919) when he said that he would gladly give half his fee to anyone who would be responsible for the retention of his results after the active appliances are removed. Parker (1989) stated in his article entitled, "Retention - Retainers may be forever", that "Experience does not give wisdom but it may and should grant perspective." With over 28 years of orthodontic experience, Gorman (1990) explained that his perspective on retention has changed from an expectation of universal stability following bicuspid extraction and two years of retention, to the realization that individual retention plans must be developed for each patient whether an extraction or nonextraction treatment regime was used.

10.2 Objectives

Controversy exists in respect to the stability of the dentition following extraction and nonextraction treatment. Only long-term evaluation of orthodontic treatment results can possibly provide answers to this dilemma.

Hence, the objectives of this part of the study were:

i) to assess whether significant differences exist between the post-treatment changes experienced in extraction and nonextraction orthodontic treatments.

ii) to determine the relationship between these groups and lower incisor irregularity.

10.3 Materials and methods

The basic materials used and methods employed in order to be able to assess the longitudinal changes experienced in the sample of eighty-eight Caucasian subjects were described in Chapter 3. The extraction group consisted mainly of premolar extractions, but the odd molar was also removed as part of a treatment regime. The sample, consisting of extraction (56%) and nonextraction (44%) treated subjects, is set out in Table I.

Orthodontic study casts and lateral cephalograms were analysed for all three stages studied as was previously described. Intra-observer error was found to be less than 1.0% and it was concluded that this error had no effect on the outcome of the results.

The study casts were measured with digital calipers capable of measuring to 0.01mm. Measurements of sagittal, transverse and vertical dimensions were included.

Cephalometric measurements were obtained with the use of the Oliceph computer program and included measurements of the popular analyses of Steiner, Tweed, Ricketts, Björk/Jarabak and Holdaway with additions such as the Wits appraisal.

The data (extraction and nonextraction) were subjected to descriptive statistics, the Wilcoxon and the Chi-square statistical tests for each of the three treatment stages studied (T1, T2 and T3) (Zar, 1984). The significance level of this part of the study was set at 0.05.

10.4 Results

The findings are set out in Tables XL, XLI, XLII, XLIII and XLIV.

TABLE XL

DIFFERENCES BETWEEN EXTRACTION AND NONEXTRACTION GROUPS FOR A NUMBER OF VARIABLES

VARIABLE		NONEXTRACTION		EXTRACTION		
		AGE				
		MEAN	S.D.	MEAN	S.D.	p
AGE	T1	11.73	1.09	12.06	1.10	0.14
	T2	14.45	2.02	14.97	1.54	0.03*
	T3	21.88	3.82	20.92	3.04	0.31
		MANDIBULAR VARIABLES				
		MANDIBLE - DIMENSIONS:				
SNB	T1	76.77	3.32	76.73	3.46	0.93
	T2	76.42	2.89	76.49	3.92	0.99
	T3	77.36	3.27	77.19	4.05	0.90
SND	T1	74.03	3.19	73.45	3.28	0.56
	T2	74.05	2.79	73.93	3.86	0.79
	T3	75.46	3.13	75.07	4.05	0.87
GOGN-MM	T1	73.74	4.22	72.22	4.64	0.17
	T2	76.54	4.55	75.62	4.94	0.39
	T3	80.10	6.01	77.73	4.73	0.08
GOGC-MM	T1	56.58	3.42	56.13	4.31	0.62
	T2	61.48	4.54	58.56	4.30	0.004*
	T3	66.42	6.57	61.43	9.73	0.01*
GOGN-GOCO	T1	123.31	4.23	126.63	4.94	0.001*
	T2	123.37	4.83	126.92	5.48	0.001*
	T3	121.33	5.30	125.77	5.67	0.001*
RAMH-MM	T1	44.15	3.78	41.99	4.29	0.02*
	T2	47.75	4.75	44.72	5.30	0.01*
	T3	54.01	6.17	49.63	6.63	0.002*
CORL-MM	T1	71.53	4.25	70.64	4.42	0.28
	T2	74.39	4.56	73.86	4.43	0.67
	T3	78.26	6.32	75.76	5.20	0.08
CORLCRAN	T1	0.99	0.08	1.01	0.17	0.59
	T2	0.99	0.06	1.01	0.56	0.39
	T3	1.02	0.07	1.01	0.63	0.75

MANDIBLE - TEETH:

MDCROWD	T1	0.99	4.67	-2.36	4.94	0.06
	T2	1.33	1.88	2.32	0.46	0.11
	T3	-2.93	4.11	-2.90	5.44	0.85
SPEE	T1	2.13	1.08	2.24	0.82	0.54
	T2	2.65	5.36	1.75	0.87	0.45
	T3	1.92	0.73	2.39	0.82	0.04*
L3-3I	T1	25.93	2.02	26.42	1.41	0.16
	T2	26.18	1.80	25.78	1.64	0.43
	T3	26.15	1.88	25.56	1.85	0.14
L3-3B	T1	29.97	2.05	30.95	1.56	0.02*
	T2	31.29	4.55	30.77	1.27	0.91
	T3	30.41	2.40	30.00	1.91	0.69
ARCHL	T1	23.76	2.17	23.12	2.41	0.29
	T2	23.31	1.87	18.92	2.36	0.0001*
	T3	22.88	2.44	17.93	2.35	0.0001*
L-IRREG	T1	2.71	2.12	5.11	3.97	0.002*
	T2	0.33	0.51	0.49	0.74	0.29
	T3	1.67	1.52	1.74	1.78	0.83
LITTLE-A	T1	62.36	3.66	59.86	4.55	0.02*
	T2	62.34	3.94	52.20	5.27	0.0001*
	T3	60.91	3.98	50.25	5.31	0.0001*
I-NB-DEG	T1	25.10	4.83	28.63	7.03	0.01*
	T2	29.12	5.39	28.06	4.77	0.41
	T3	27.41	4.38	26.55	4.75	0.31
I-NB-MM	T1	2.92	1.61	4.50	2.12	0.0003*
	T2	4.41	1.66	4.22	1.53	0.57
	T3	4.14	1.57	4.04	1.69	0.42
I-APO-MM	T1	-1.14	2.29	1.43	2.55	0.0001*
	T2	1.14	2.29	1.34	1.56	0.94
	T3	0.66	2.27	1.04	1.65	0.79
I-APO-DEG	T1	22.56	4.45	24.58	5.55	0.09
	T2	29.38	5.28	26.64	3.65	0.008*
	T3	29.11	4.24	26.49	4.18	0.01*
IMPA	T1	97.86	5.64	95.94	13.63	0.82
	T2	101.77	6.28	96.52	5.61	0.0003*
	T3	101.34	5.28	95.79	5.83	0.0001*
FMIA	T1	62.63	4.88	59.00	7.68	0.01*
	T2	58.70	5.51	59.49	5.83	0.48
	T3	59.34	11.29	61.84	6.29	0.45

MANDIBLE - GROWTH DIRECTION:

GOGN-SN	T1	31.13	3.45	35.08	5.25	0.0004*
	T2	31.59	4.06	35.71	6.24	0.002*
	T3	29.36	4.34	34.23	6.79	0.0003*
FMA	T1	20.65	3.74	24.68	4.45	0.0001*
	T2	20.68	4.19	25.13	5.37	0.0003*
	T3	18.03	7.27	23.71	5.73	0.0001*
FAC-AXIS	T1	90.16	3.18	87.91	4.59	0.02*
	T2	89.55	3.47	87.38	5.06	0.03*
	T3	90.83	3.77	88.26	5.86	0.05*
FAC-TAPE	T1	70.92	3.27	66.99	3.69	0.0001*
	T2	70.07	3.51	66.28	3.90	0.0001*
	T3	71.59	3.81	67.54	4.37	0.0001*
MAND-ARC	T1	32.48	4.42	28.40	5.16	0.0004*
	T2	33.16	5.21	29.33	5.65	0.001*
	T3	35.99	5.46	32.69	5.55	0.03*
FAC-ANGL	T1	89.05	2.74	87.94	3.16	0.09
	T2	89.53	3.11	88.54	3.62	0.22
	T3	90.72	3.27	89.55	3.80	0.20
L-FACH	T1	41.08	3.32	45.34	4.21	0.0001*
	T2	42.69	3.95	45.99	5.04	0.002*
	T3	42.20	4.26	45.40	5.19	0.002*
ARTANGLE	T1	145.53	7.29	147.15	6.69	0.33
	T2	144.87	6.76	147.46	7.72	0.16
	T3	145.14	8.01	147.18	7.19	0.33
GONANGLE	T1	121.40	4.89	125.82	5.98	0.0001*
	T2	122.06	5.85	125.69	6.24	0.01*
	T3	118.77	6.25	123.58	6.08	0.001*
SUMANGLE	T1	391.00	3.69	395.94	5.55	0.0001*
	T2	391.81	4.16	396.25	6.47	0.001*
	T3	388.87	4.45	393.93	6.94	0.0003*
GONSLING	T1	51.73	4.08	51.81	4.17	0.85
	T2	51.03	4.19	50.76	4.83	0.88
	T3	49.26	4.46	49.67	4.16	0.51
CORSLING	T1	69.64	3.06	51.81	4.17	0.0001*
	T2	71.03	3.53	74.93	4.76	0.0001*
	T3	69.52	3.55	73.92	5.49	0.0001*

p = Significance level, p <0.05 (WILCOXON 2-Sample Test)
* = Significant differences, p < 0.05

TABLE XLI

DIFFERENCS BETWEEN EXTRACTION AND NONEXTRACTION GROUPS FOR MAXILLARY VARIABLES

VARIABLES		NONEXTRACTION		EXTRACTION		
		MEAN	S.D.	MEAN	S.D.	p
		MAXILLA - DIMENSIONS:				
SN-FH	T1	10.40	2.92	10.48	1.95	0.62
	T2	10.91	2.40	10.58	2.76	0.70
	T3	10.68	2.47	10.52	2.67	0.93
SNA	T1	81.06	3.37	81.44	3.88	0.57
	T2	79.39	3.16	79.62	3.86	0.97
	T3	79.98	3.39	79.97	3.49	0.85
ANSPNS-SN	T1	7.86	2.87	7.29	2.96	0.37
	T2	8.28	2.85	8.08	3.58	0.72
	T3	7.81	2.89	7.90	3.34	0.92
A-CONVEX	T1	4.08	2.54	3.45	3.07	0.49
	T2	1.40	2.47	2.33	2.75	0.17
	T3	0.50	2.89	1.61	3.04	0.14
SADANGLE	T1	122.99	4.19	124.04	5.14	0.24
	T2	124.88	4.83	123.11	4.74	0.10
	T3	124.90	5.17	123.17	4.72	0.15
SN-MM	T1	71.61	3.21	72.02	3.32	0.23
	T2	74.57	3.24	73.29	3.37	0.05*
	T3	77.06	4.21	75.03	4.01	0.01*
SAR-MM	T1	34.35	2.86	35.63	4.07	0.12
	T2	37.25	4.06	35.98	2.83	0.13
	T3	38.06	4.67	36.81	3.15	0.17

MAXILLA - TEETH:

MXCROWD	T1	1.92	5.48	-1.78	6.16	0.09
	T2	----		-1.46	0.74	----
	T3	-0.78	4.13	-1.97	5.57	0.38
U6-6I	T1	50.81	4.15	48.59	2.95	0.01*
	T2	52.96	3.13	48.08	2.84	0.0001*
	T3	50.97	3.05	48.63	2.91	0.001*
U6-6B	T1	54.33	4.02	52.13	2.96	0.01*
	T2	57.16	6.52	52.02	3.01	0.0001*
	T3	54.36	2.99	52.21	2.72	0.001*
I-NA-DEG	T1	23.64	10.45	22.19	7.96	0.32
	T2	23.33	9.18	21.85	7.49	0.39
	T3	23.02	8.03	21.72	6.42	0.40
I-NA-MM	T1	3.92	3.25	4.14	2.53	0.83
	T2	3.16	3.04	2.57	2.17	0.44
	T3	3.76	3.01	3.37	2.12	0.71
I/-FH-DEG	T1	115.34	10.46	113.45	7.21	0.16
	T2	113.41	8.63	111.83	7.55	0.35
	T3	113.46	7.76	111.99	6.20	0.31
I/-FACAX-DEG	T1	4.52	9.93	4.01	7.64	0.94
	T2	6.11	7.79	5.31	6.89	0.77
	T3	6.84	6.38	5.85	5.72	0.54
I/-APO-MM	T1	6.74	3.32	7.43	2.81	0.58
	T2	4.24	1.99	4.31	1.49	0.97
	T3	4.18	2.14	4.59	1.76	0.53
UM-PTV-MM	T1	16.65	3.54	17.36	4.01	0.21
	T2	17.69	4.16	22.05	4.47	0.0001*
	T3	21.97	3.42	23.45	4.94	0.10
UM-CCV-MM	T1	15.55	3.45	16.24	4.03	0.24
	T2	16.41	4.27	20.63	4.35	0.0001*
	T3	20.46	3.66	21.89	5.09	0.11

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differencs, $p < 0.05$

TABLE XLII

DIFFERENCES BETWEEN EXTRACTION AND NONEXTRACTION GROUPS FOR MAXILLARY TO MANDIBULAR VARIABLES

VARIABLE		NONEXTRACTION MEAN	NONEXTRACTION S.D.	EXTRACTION MEAN	EXTRACTION S.D.	p
		MAXILLA TO MANDIBLE:				
ANB	T1	4.67	2.74	4.33	2.12	0.44
	T2	2.96	2.13	3.13	1.86	0.92
	T3	2.62	2.31	2.78	2.15	0.96
POSFACH-MM	T1	76.06	4.81	73.14	4.73	0.01*
	T2	80.75	6.72	77.32	5.49	0.01*
	T3	87.75	8.32	82.56	7.09	0.003*
ANTFACH-MM	T1	114.39	5.78	116.84	5.75	0.07
	T2	121.74	8.25	122.89	6.22	0.55
	T3	126.39	9.36	126.22	6.59	0.64
SGO-NME	T1	66.54	3.41	62.70	4.45	0.0001*
	T2	66.55	3.86	63.05	5.16	0.001*
	T3	69.44	4.17	65.49	5.42	0.001*
WITS-MM	T1	2.41	3.82	0.29	3.85	0.004*
	T2	0.63	3.45	0.29	2.79	0.38
	T3	1.58	3.89	0.19	3.41	0.09

OCCLUSION:

OJB	T1	6.93	3.63	5.59	2.86	0.04*	
	T2	3.01	0.93	2.74	0.78	0.24	
	T3	3.18	1.25	3.21	1.23	0.73	
OBB	T1	4.64	1.38	3.87	1.46	0.03*	
	T2	3.00	1.02	2.61	0.86	0.14	
	T3	2.75	0.89	2.86	1.30	0.99	
BOLTON A	T1	78.69	1.53	78.12	2.57	0.56	
	T2	-----					
	T3	77.98	2.55	77.10	8.47	0.67	
BOLTON P	T1	92.06	1.75	91.13	2.03	0.33	
	T2	-----					
	T3	91.29	2.54	89.11	8.74	0.89	
I-I	T1	127.71	11.28	125.98	10.97	0.58	
	T2	125.73	10.73	128.09	7.69	0.18	
	T3	130.09	6.72	128.09	8.40	0.16	
OCC-SN	T1	15.91	5.60	17.71	4.97	0.09	
	T2	16.98	3.59	18.18	4.60	0.32	
	T3	16.59	5.52	14.03	3.67	0.06	
MOLAR L	T1					0.003*	x
	T2					0.33	x
	T3					0.73	x
MOLAR R	T1					0.01*	x
	T2					0.43	x
	T3					0.69	x
CANINE L	T1					0.03*	x
	T2					0.31	x
	T3					0.95	x
CANINE R	T1					0.02*	x
	T2					0.26	x
	T3					0.17	x
OPENBIT	T1					0.94	x
	T2					0.79	x
	T3					0.54	x
ANTXBIT	T1					0.06	x
	T2					----	
	T3					0.83	x
POSTXBIT	T1					0.19	x
	T2					0.47	x
	T3					0.23	x
ROTATE	T1					0.49	x
	T2					0.09	x
	T3					0.13	x

p = Significance level, p < 0.05 (WILCOXON 2-Sample Test)
* = Significant difference, p < 0.05
x = CHI-SQUARE Test

TABLE XLIII

DIFFERENCES BETWEEN EXTRACTION AND NONEXTRACTION GROUPS FOR SOFT TISSUE VARIABLES

VARIABLES		NONEXTRACTION		EXTRACTION		
		MEAN	S.D.	MEAN	S.D.	p
U-LIPE-MM	T1	-1.35	2.15	-0.79	2.49	0.01*
	T2	-4.19	1.94	-4.19	1.89	0.88
	T3	-6.00	2.76	-5.72	2.07	0.14
Z-ANGLE	T1	71.61	6.27	68.58	7.83	0.06
	T2	75.49	5.22	74.65	6.55	0.49
	T3	77.04	14.31	76.78	6.80	0.16
L-LIPE-MM	T1	-0.69	2.67	1.14	2.92	0.01*
	T2	-2.32	1.96	-2.14	2.12	0.88
	T3	-4.17	2.34	-3.37	2.84	0.18
STFAC	T1	89.84	2.99	88.64	3.48	0.08
	T2	90.31	3.20	89.34	3.98	0.19
	T3	91.89	3.21	90.33	3.82	0.07
NOSE-MM	T1	13.04	1.59	13.30	2.22	0.74
	T2	15.78	2.21	15.99	1.97	0.88
	T3	18.15	2.50	17.91	2.22	0.69
SUPSULD	T1	-9.59	3.21	-9.78	2.78	0.68
	T2	-8.76	3.09	-8.98	2.59	0.69
	T3	-8.19	3.20	-8.29	3.22	0.49
SAHLINE	T1	6.08	2.06	7.14	2.16	0.03*
	T2	4.72	2.06	4.86	1.38	0.95
	T3	4.53	1.92	4.89	1.55	0.26

ULIPTH-MM	T1	15.04	1.75	14.43	1.26	0.11
	T2	16.28	2.14	15.60	1.97	0.09
	T3	16.82	2.23	16.18	2.11	0.14
ULIPTAP-MM	T1	11.61	2.50	11.37	1.89	0.71
	T2	13.66	1.82	13.22	2.06	0.22
	T3	13.99	2.30	13.15	2.72	0.09
ULIPSTR-MM	T1	3.43	2.14	3.06	1.89	0.33
	T2	2.62	1.79	2.38	1.52	0.37
	T3	2.83	1.81	3.03	2.19	0.65
HANGLE	T1	16.79	3.98	16.90	3.79	0.89
	T2	13.76	3.66	13.36	2.74	0.65
	T3	12.34	4.08	12.37	3.30	0.93
LIPH-MM	T1	0.21	1.91	1.67	2.06	0.003*
	T2	0.49	1.29	0.75	1.57	0.42
	T3	0.03	1.35	0.49	1.88	0.10
ISULH-MM	T1	6.09	2.08	4.30	2.21	0.0002*
	T2	5.42	1.85	4.45	1.89	0.03*
	T3	6.08	2.07	5.03	2.43	0.02*
STCHIN-MM	T1	10.04	2.15	10.14	2.08	0.95
	T2	10.37	1.80	10.50	2.24	0.96
	T3	11.18	2.27	11.26	2.46	0.91

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differences, $p < 0.05$

TABLE XLIV

DIFFERENCES BETWEEN EXTRACTION AND NONEXTRACTION GROUPS: DESCRIPTIVE STATISTICS FOR THE LITTLE IRREGULARITY INDEX (Little, 1975)

EXTRACTION:

	T1		T2		T3	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
L-IRREG	5.11*	3.97	0.49	0.74	1.74	1.78

NONEXTRACTION:

	T1		T2		T3	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
L-IRREG	2.71*	2.12	0.33	0.51	1.67	1.52

S.D = Standard deviation
* = Statistically significant difference, $p < 0.05$ (WILCOXON 2-Sample Test)

Significant age differences were only experienced at the end of appliance therapy (T2), possibly due to the treatment periods not all being of similar duration for the extraction and nonextraction groups.

The mandibular dimensions (GOGC-MM at T2 and T3; GOGN-GOCO at T1, T2 and T3; RAMH-MM at T1, T2 and T3), as well as mandibular growth direction (GONANGLE, SUMANGLE, CORSLING, GOGN-SN, FMA, FAC-AXIS, FAC-TAPE, MAND-ARC and L-FACH at T1, T2 and T3) showed significant differences between the extraction and the nonextraction groups. The mandibular dental arch differences were limited to arch length (ARCHL at T2 and T3 and LITTLE-A at T1, T2 and T3), lower incisor axial inclination (I-NB-MM and I-APO-MM at T1; I-APO-DEG and IMPA at T2 and T3; FMIA at T1) (Table XXXVII). Mandibular intercanine width (L3-3B) showed significant differences at the start of treatment (T1) only and the Curve of Spee (SPEE) at the post-retention phase only (T3) (Table XL).

The Little Irregularity Index (Little, 1975) showed significant differences at the pre-treatment observation (T1) only. No significant differences were measured at the end of the active orthodontic treatment (T2) and at the final observation (T3) between the two groups (Table XL and XLIV).

The only upper facial dimension which displayed a statistical difference was the anterior cranial base length (SN-MM at T2 and T3). Dental arch width measured as the maxillary bimolar dimension showed differences between the groups throughout the study (T1-T3). The upper first molar position (UM-PTV-MM and UM-CCV-MM) showed differences only at the end of treatment (T2) (Table XLI).

Assessment of the maxillary-mandibular relationships showed a statistical significant difference between the extraction and nonextraction groups and that occurred in the posterior facial height (POSFACH-MM) at all three obsrevations (T1-T3). Differences in the posterior facial height also affected the percentage ratio between the anterior and posterior facial heights (SGO-NME) which showed significant differences at all three the stages studied. The WITS-MM showed statistically significant differences only at the commencement of the treatment (T1) (Table XLI).

The occlusal variables which showed significant differences (OJB, OBB, MOLAR L, MOLAR R, CANINE L, CANINE R) did so only at the start of the treatment (T1) (Table XLII).

The soft tissue parameters showed differences only at the beginning of treatment (U-LIPE-MM, L-LIPE-MM, SAHLINE, LIPH-MM, ISULH-MM at T1). Following treatment only the inferior lip sulcus depth to the H-line (ISULH-MM at T2 and T3) displayed statistically significant differences and then only at the end of treatment and at the end of the post-orthodontic phase (Table XL).

The differences in the descriptive statistics of the Little Irregularity Index between the two groups are set out in Table XLIV. The pre-treatment (T1) lower incisor irregularity showed a significant difference between the groups, but no significant differences were measured at the other observations (T2 and T3).

10.5 Discussion

Spectacular results achieved as a result of orthodontic treatment are very impressive and greatly admired. The problem lies in the fact that failures, too, occur often. Treatment reliability, therefore, depends upon proof that the proportion of success is greater than that of failures. Hellman (1943) mentioned that to ascertain the relationship between the successes and the failures in orthodontics requires long stretches of time. Although a number of long-term studies (Sadowsky and Sakols, 1982; Little, 1990; McReynolds and Little, 1991) discuss the stability and relapse of post-treatment orthodontic results, there are still numerous debates as to whether extraction or nonextraction therapy produces more stable results.

Does extraction solve all our problems? A very positive no! Without meticulous planning, extraction therapy will result in unwarranted and unjustifiable failures (Nance, 1947).

The assessment of the data of this study indicated certain significant differences between extraction and nonextraction groups.

The significant difference in age at the end of treatment (T2) is probably not of any clinical significance as it is expected that treatment time will differ for individual subjects and more so when comparing males and females with their different growth curves (Table XL).

The mandibular dimensions (GOGN-GOCO and RAMH-MM), the lower intercanine width (L3-3B), the lower incisor position (I-NB-MM, I-APO-MM and FMIA), the incisor irregularity (L-IRREG), the arch length (LITTLE-A) and mandibular growth pattern (GOGN-SN, FMA, FAC-AXIS, FAC-TAPE, MAND-ARC, L-FACH, GONANGLE, SUMANGLE and CORSLING) all showed significant differences between the two groups at the start of treatment (T1) (Table XL). Upper bimolar width (U6-6I and U6-6B) showed similar differences (Table XLI). The mensuration of the group differences of the maxillary to mandibular data at the start of treatment (T1) also revealed significant differences. They were the antero-posterior discrepancy (ANB and WITS-MM), the anterior to posterior facial height ratios (ANTFACH-MM, POSFACH-MM and SGO-NME), overbite and overjet (OBB and OJB) as well as molar and canine relationships (MOLAR L, R and CANINE L, R) (Table XLII). Soft tissue variable differences at the start of treatment included the lower and upper lip to the E-line (U-LIPE-MM and L-LIPE-MM), the lower lip to H-line (LIPH-MM), the upper lip curl (SAHLINE) and the inferior lip sulcus (ISULH-MM) (Table XLIII). All of these significant differences could be expected. They not only justify the reasons for the differences in treatment regimes, but also ackowledge the fact that orthodontists possibly made the correct decisions regarding the extraction, or nonextraction approaches to treatment.

The end of active orthodontic treatment (T2) normally signifies the achievement of ideal occlusal and soft tissue parameters. Functional and aesthetic results which please both the orthodontist and the patient symbolises ultimate success.

The variables measured at the end of mechanical therapy (T2) again showed significant differences between the extraction, and nonextraction subjects. Mandibular differences still included those which indicate the morphological differences which were preserved. The only addition to these measurements was the change in posterior mandibular growth that took place during the treatment period (T1-T2). This finding is exemplified by the measurement from Gonion to Condylion (GOCO-MM) (Table XLI). The mandibular dental dimensions including the intercanine dimension, the curve of Spee and the irregularity of the lower incisors showed no significant differences which can be ascribed to good orthodontic technique. This is expected irrespective of the treatment regime. The lower incisor position showed angular differences between the two groups (I-APO-DEG and IMPA). Although it appears as if the lower incisor goals for both groups were attained, the two angular differences mentioned above could be ascribed to the cephalometric landmarks used. The measurments recorded in relation to the Point A-Pogonion line can be influenced by the chin button shape (FAC-TAPE). It is known that brachycephalic and dolichocephalic facial patterns, mensurated by GOGN-SN, FMA, FAC-AXIS, FAC-TAPE, MAND-ARC and L-FACH, do differ in this respect and that the extraction philosophy is also different for the two types of facial patterns (Tweed, 1966; Ricketts et al., 1979). The IMPA (Tweed, 1954) could also be influenced by growth changes in the lower mandibular border as were shown by Björk and Skieller (1983). Mandibular dimensions are different for vertical and horizontal growers. Horizontal growers show a flatter mandibular plane when compared to the more acute mandibular plane of the vertical grower which is characterized by strong antegonial notching (Ricketts et al., 1979; Lambrechts, 1991). Differences in the arch length (ARCHL and LITTLE-A) between extraction and nonextraction subjects were expected. The arch length does not only decrease because of the natural phenomenon of mesial migration or drifting (Moyers et al., 1976; Moyers, 1988), but also due to extractions which caused tremendous differences in this dimension. This finding supported studies showing a decrease in arch length (Shapiro, 1974; Gallerano, 1976; Little, Wallen and Riedel, 1981; Little and Riedel, 1989; Little, Riedel and Engst, 1990). Similar changes occur in untreated individuals (Sinclair and Little, 1983).

Maxillary variables also showed some expected significant differences between the extraction and nonextraction groups (Table XLI). The anterior cranial base measurement, Sella-Nasion (SN-MM), was significantly different between the groups at the end of treatment (T2). This finding can be ascribed to a possible enlargement of the frontal sinus with an accompanying forward bulging of the frontal bone. Due to these growth changes Nasion could have been displaced forwards. Jacobson (1975) used the Wits appraisal of jaw disharmony to show how different positions of Nasion could influence the basic grouping of a malocclusion. It was shown in a cross-sectional study that mandibular growth correlates with increases in frontal sinus size (Rossouw, Lombard and Harris, 1991). As was previously noted, extraction or nonextraction treatment will to some extent be dependent on the mandibular morphology. The maxillary bimolar width (U6-6I and U6-6B) was significantly different between the groups at all the observation periods (T1-T3), but the position of the maxillary first molar to the pterygoid root vertical (PTV) (UM-PTV-MM) and centre of the cranium (CCV) (UM-CCV-MM) showed significant differences only at the end of treatment (T2). As the molars move forwards due to extractions, loss of leeway or normal growth, it may be expected that these dimensions (T1, T2 and T3) will change. Extraction of premolars results in a forward movement of the molars into a narrower part of the alveolar trough which results in narrowing of the bimolar width. The opposite is of course also true when the first molars are distalized using extra-oral traction. Decreases in arch width have also been reported in a second premolar extraction study (McReynolds and Little, 1991).

Antero-posterior maxillo-mandibular discrepancies may also be influenced by facial patterns (brachifacial or dolichofacial) or treatment regimes. Extractions for example may cause the mandibular plane angle to rotate in a forward closing direction. With headgear and Class II intermaxillary elastic wear the lower facial height may be increased. Natural mandibular growth rotation (Björk and Skieller, 1983) in the various growth patterns will also account for differences in extraction and nonextraction groups. Due to these rotations the ratio of anterior and posterior facial heights (SGO-NME) as well as the posterior facial height (POSFACH-MM) were significantly different for the groups (Table XLI).

Interestingly enough, the different occlusions appeared to have been treated to similar occlusal goals for both groups (Table XLII and XLIV). The ultimate aim was, probably to achieve the six keys of occlusion in all the treated subjects (Andrews, 1972, 1976). Good orthodontic technique in order to achieve these goals is imperative and played a major role in producing occlusions with no significant differences at the end of treatment (T2) and at the end of the post-orthodontic phase (T3). Tooth-size discrepancies (Bolton, 1958) could be an aetiologic factor in causing malocclusions as well as leading to an extraction treatment regime (Bahreman, 1977; Kokich and Shapiro, 1984), but fortunately it can be corrected by a process of interproximal enamel stripping (Joseph, Rossouw and Basson, 1991). No significant differences were, however, detected in the Bolton relationships between the groups (Table XLII).

Soft tissue profile assessment is an important aid in total orthodontic evaluation. Soft tissue can be grossly influenced if extractions are performed in a nonextraction facial profile. Holdaway (1983, 1984) emphasised this fact with his soft tissue analysis and visual treatment objective. Initial significant differences in soft tissue variables were expected. Sound diagnosis and subsequent correctly treated orthodontic subjects should not necessarily produce major differences in soft tissue profile whether treated extraction or nonextraction. This is borne out by the non-significant differences which was observed between the groups at the end of treatment (T2) and at the final observation (T3) (Table XLIII). The only soft tissue variable showing a significant difference at the end of treatment and the post retention phase was the inferior lip sulcus (ISULH-MM). This difference can be accounted for by the fact that the morphology of the chin button, a slight proclination or retroclination of the lower incisors and an enlarged overbite or overjet may affect this dimension. The mean lower incisor axial inclination was slightly proclined in this study during the orthodontic treatment (Table XXXIV, Chapter 8), although the millimetre distance of the incisor tip to the various lines (NB and APo) was within norms.

An analogy suggesting that teeth move as long as we live, just as surely as our hair colour changes throughout our lives, possibly explains some of the post-treatment changes measured (Parker, 1989). Changes in the parameters of this study between the end of treatment (T2) and the end of the post-orthodontic phase (T3) indicated the rebound or relapse so often referred to in the literature (Little, Wallen and Riedel, 1981; Sadowsky and Sakols, 1982; Shields, Little and Chap[illegible] 1985; Little and Riedel, 1989; McReynolds and Little, 1991).

Similar differences which occurred in the mesial positions of the first maxillary molars at end of treatment (T2) were also significant when measured at the final observation (T3) for the two groups. The only variables which became non-significant were depended on the movement of the first molars (UM-PTV-MM and UM-CCV-MM) (Table XLI). Some settling or rebound movement obviously took place and in so doing eliminated the previous differences (end of treatement) between the two groups. An analysis of variance showed that the molar positions from the end of treatment to the final observation (T2-T3), however, remained reasonably stable. No significant changes occurred after the achievement of the post-treatment molar and canine relationships. Behrents et al. (1989) reported similar findings.

Extractionists and nonextractionists can show excellent results and offer persuasive arguments for their philosophies. Extractionists will usually rely on the lower incisor position as their key cephalometric measurement (Williams, 1969, 1985). The nonextractionist again will likely focus on an articulation where all the teeth are made to fit. These orthodontists will sometimes "develop" the arches by starting the treatment with functional appliances in the early mixed dentition. If the teeth are, irrespective of the type of treatment, correctly placed for the individual, good aesthetics will follow, the finished dentition will be stable and facial harmony will be achieved.

The aesthetic rewards of straight teeth and a gorgeous smile following orthodontic treatment are sought by both orthodontist and patient. Boley (1991, 1992) presented data in respect to soft tissue features which were objectively recorded by leading orthodontists in the USA following orthodontic treatment. No significant differences ($p < 0.05$) could be shown between the facial profiles of subjects who had extraction or nonextraction treatment. Orthodontists, however, have the added responsibility of achieving functional occlusions. If this harmony is achieved, one may well be on the way to achieving long-term stability (Conlin, 1989).

Early intervention for the correction of orthodontic problems has been a neclected phase of orthodontic treatment for too long a time (Barnes, 1955). Being able to clinically assess young orthodontic subjects and realising the use of natural spaces available, including the primate and the leeway spaces (Moorrees and Chadha, 1962), will certainly enable many occlusions to be treated nonextraction. The responsibilty in educating new dentists and orthodontists to this philosophy cannot be overemphasized.

The indicator used in this study to determine lower incisor alignment, the Little Irregularity Index (Little, 1975), indicated a more severe situation for the extraction group at T1. The mandibular crowding, as was clinically measured (MDCROWD), supported this lower incisor irregularity at T1 although the statistically significant level was fractionally exceeded ($p = 0.06$). This indicated that the correct diagnosis was made in treating with extractions. A value of practically zero was achieved for the Little Irregularity Index at the end of active treatment (T2). A slight relapse occurred in both groups, but no significant difference was shown in the lower incisor irregularity at T2 and T3 (Table XLIV). The relapse or rebound as indicated from T2 to T3 was well within clinically acceptable standards (Little, 1975). Both groups showed similar changes. Moreover, it can be concluded that when competent orthodontists select an extraction, or nonextraction orthodontic treatment regime for the correction of malocclusions, there need not be any significant differences between the post-treatment results of the groups. Patients must however be informed of the benefits and disadvantages of both treatment regimes.

10.6 Conclusions

1. The extraction of teeth does not necessarily assure long-term stability of the lower incisors.
2. The differences experienced between extraction and nonextraction groups were mainly maxillary and mandibular dimensional as well as growth pattern differences.

3. The Little Irregularity Index (Little, 1975) showed no significant ($p > 0.05$) differences between the extraction and nonextration groups at T2 and T3.

4. Meticulous orthodontic care, including proper diagnosis in order to distinguish between extraction and nonextraction malocclusions, is imperative.

5. The extraction versus nonextraction controversy seems to be here to stay.

CHAPTER 11

SOFT TISSUE CHANGES RESULTING FROM ORTHODONTIC TREATMENT AND THEIR RELATIONSHIP TO LOWER INCISOR IRREGULARITY

11.1 Introduction

In the orthodontic literature various authors have expressed opinions about faces and profiles. Edward Angle, considered to be the father of modern orthodontics, was one of the first to write about facial harmony and the importance of the soft tissues. He referred to the mouth as being the facial feature most able to make or mar the beauty and character of the face. He added that "orthodontics is indissolubly connected with studies of art as related to the human face" (Angle, 1907). Angle's concept of facial harmony was further expanded by Wuerpel (1931), who stated that "a variety of faces can be considered to be beautiful provided that their proportions are in balance". Wuerpel in describing facial balance noted that one part of the face should not be overemphasized at the expense of another.

A review of art taken from Egyptian times, the height of the Greek and Roman Empires and the periods influenced by the modern French, Italians, and Germans shows constantly changing concepts as to what constitutes a beautiful profile. In modern times, straight profiles have been selected by newspapers, magazines, movies, and theatres as being the most popular (Hambleton, 1964).

The disciplines of psychology and sociology help to identify aesthetic preferences in different ethnic groups. Such studies have, however, shown that there is a surprising degree of agreement among different population groups regarding facial preferences (Peck and Peck 1970). In a study to determine whether the dentofacial appearance contributes to the attractiveness of a young adult, it was concluded that faces displaying normal incisor relationships gained the most favourable ratings. Of the different facial characteristics examined, good incisor appearance was rated highest as indicating friendliness, social class, popularity, and intelligence. Unilateral palatal clefts were consistently, in the public eye, associated with negative character traits (Shaw, Rees, Dave and Charles, 1985). Lay persons are more likely to rate an individual's profile as being normal than would orthodontists and oral surgeons. Individuals perceive their own profiles differently, than do others, who are asked to do so (Bell, Kiyak, Joondeph, McNeill and Wallen, 1985).

Judgments of facial aesthetics tend to be subjective. An appropriate goal for orthodontic treatment is to improve facial harmony by correcting facial disproportions (Proffit 1986; Bishara, Hession and Peterson 1985).

Soft tissue and skeletal measurements made on lateral head films show that males and females with poor facial balance have more convex faces (Bishara, Hession and Petersen, 1985). Furthermore, males with poor facial harmony show more protrusive incisors. A number of faces with good facial harmony were found in association with malocclusions. This raises the question as to whether cephalometric standards have been set too rigidly and with too little freedom for variation (Cox and Van der Linden, 1971). It should be kept in mind that all profile evaluations should be made with care (Barrer and Ghafari, 1985).

With time, orthodontists have become increasingly aware that facial aesthetics, and not only the occlusion, should be considered when planning orthodontic treatment (Rakosi 1982). Usually when orthodontists correct malocclusions they improve the appearances of their patients. Most experienced orthodontists, however, have made the unpleasant discovery that some patients looked "better" prior to orthodontic intervention. Practitioners should determine beforehand what orthodontic treatment will accomplish in terms of facial apprearance (Holdaway 1983).

In trying to provide good facial aesthetics vertical profile characteristics are as important, as are anteroposterior features and a lengthening of soft tissue profiles is rarely desirable (De Smit and Dermaut, 1984).

Common aesthetic standards for lip posture were determined by Foster (1973) who believed that younger individuals have "fuller" lips. He also proposed that in general normal adult males tend to have less prominent lips than have females of the same ages. This observation holds true for mature faces which with age get more concave in the lip region. The latter finding is particularly true for females (Mauchamp and Sassouni, 1973).

Radiographic cephalometric studies of craniofacial growth should take account of the facial soft tissues as well as of the underlying hard tissues (Bishara, Hession and Peterson, 1985).

The above studies demonstrate that there is a definite need to establish harmonious relationships between the dental and facial features. Some attempts have been made to quantify facial growth and maturational changes. Simon (1924) attempted to divide the head into planes and to relate profile contours to the Frankfurt horizontal and orbital planes. He used photographs to measure soft tissue growth and other facial changes.

In 1922 Case made facial casts of patients prior to and following orthodontic treatment. As a result of this work he stated that, in the correction of malocclusions, the facial outlines should be regarded as being important in developing a proper treatment plan. He did emphasize the complexity of the problem by showing three different profiles, each with a similar Class I malocclusion.

Tweed (1944) gave special attention to aesthetics and stated that a thorough knowledge of the normal growth pattern of the face is as important to orthodontists, if not more so, as is a complete mastery of the science of occlusion. Using cephalometric standards, in a cross-sectional study of 95 patients with "good facial esthetics", he emphasized the importance of the Frankfurt-mandibular incisor angle (FMIA) and the use of the diagnostic triangle in the treatment planning and prognosis.

It is important to note that, up to 1950, most Cephalometric studies were concerned with bony tissues as it was assumed that the soft tissue profile was dependant on the underlying skeletal configuration.

Not all parts of the soft tissue profile follow changes in the underlying skeletal structures in a strictly linear fashion (Subtelny, 1959). This finding may be due to the variation in the thickness of the soft tissue covering the skeletal face (Burstone, 1967).

Computerized cephalometric analyses and stereophotogrammetry have been used in studies of the facial profiles in an attempt to quantify growth and treatment changes in the overall profile, as well as in its various components (Chaconas et al., 1990). Angular and planar measurements provide essential information in respect of changes in facial morphology. If two parts of a face grow in complete harmony the angular relationships between these two parts will remain essentially the same. Linear measurements, are probably best used to quantify the amount of growth expressed by a particular component of a face (Broadbent, Broadbent and Golden, 1975; Riolo et al., 1974; Bishara, Peterson and Bishara, 1984).

Soft tissue analyses have been proposed to evaluate profiles and these point to the fact that cognizance must be taken of ethnic differences in soft tissue profiles (Peck and Peck, 1970; Thomas, 1979; Ricketts, 1982; Holdaway, 1983; Proffit, 1986). Some analyses which appear to have the most clinical value may have insufficient documentation in respect of longitudinal facial changes. This fact could affect the applicability of such analyses in patients of different ages.

11.1.1 Longitudinal changes in the soft tissue profile

The exact relationship between the bony skull and its facial drape of soft tissue is not fully understood. Angle (1907) claimed that a dentition which is arranged according to given standards, will ensure that the facial soft tissues are displayed in a harmonious manner. Fifty years later this viewpoint still found some support (Riedel, 1957). The existence of an absolute relationship between the hard and soft tissues of the face was doubted by some (Burstone, 1958; Neger, 1959). Subtelny (1959, 1961) made the point that the bony facial profile tends to become more concave with age. This increase in the concavity of the total soft tissue profile, partly as a result of the increase in the size of the nose, was also noted by others (Chaconas and Bartroff, 1975; Genecov, Sinclair and Dechow, 1990). The soft tissue profile, excluding the nose from the profile analysis, shows a tendency to remain relatively stable in its degree of convexity. This view is supported by Bishara, Hession and Petersen (1985) following their longitudinal study in respect of soft tissue changes not analogous to those of hard tissue skeleton. At the same it seems that all parts of the soft tissue profile did not directly follow the underlying skeletal profile changes (Subtelny, 1961; Genecov, Sinclair and Dechow, 1990).

11.1.2 Changes in the components of the soft tissue profile

11.1.2.1 Glabella

Soft tissue Glabella becomes more prominent well into adult life. Beside the presence of sexual dimorphism in size, it is evident that the location of Glabella is higher in females than in males. In both sexes Glabella tends to move downwards with time as does soft tissue Nasion (Behrents, 1984).

11.1.2.2 Nose

In both sexes the most anterior point of the nose continues to move forwards and downwards with age (Subtelny, 1959, 1961; Ricketts, 1960). Although males have larger noses than females there appears to be no sexual dimorphism in respect of the angular relationships of the nose to the cranial base. The angle formed by a continuation of the bridge of the nose and the columella becomes more acute during the later stages of development (Subtelny, 1961). It was reported that subjects with straight profiles tend to have straight noses (Robison, Rinchuse and Zullo, 1989). At the same time those with convex profiles tend to have convex noses and those with concave profiles tend to have concave noses.

11.1.2.3 Lips

The nasiolabial angle becomes more acute with age. Soft tissue A point has a downwards and forwards direction of movement during growth of the nasomaxillary complex and the downward movement becomes more apparent as the lip lengthens. Stomion follows the same direction during growth as it moves away from the Anterior Nasal Spine. The lower lip also follows this behaviour, as does soft tissue B point. The angle formed by the lower lip, mental sulcus and Pogonion becomes deeper for the female, perhaps as the result of a relatively more prominent lower lip and a lesser forward movement of soft tissue B point (Behrents, 1984). Males, however, have larger and more prominent lower lips. Both sexes show a tendency to a relatively less prominent upper lip with the passage of time. The nose relates continually to the movements of Stomion with age having little or no effect. This suggests that the whole midface is moving proportionately downwards and forwards through time. As the skeletal profile straightens, or becomes more concave, so soft tissue Pogonion becomes more prominent with age and it may be expected that the upper lip will flatten as it elongates (Behrents, 1984). The vermilion aspect of the lips, especially of the lower lip, was concomitantly observed to become more retruded in relation to the facial profile (Subtelny 1959). Following the complete eruption of the anterior teeth, the lip embrasure has been found to be closely related to the incisal edges of the incisors. After about nine years of age, the upper lip was found to cover just more than sixty per cent of the maxillary central incisor crown. The remainder of this tooth is of course, usually covered by the vermilion aspect of the lower lip (Subtelny, 1961). In the relaxed position a small vertical space or interlabial gap is normally found between the upper and lower lips. In malocclusions and facial disharmonies, the interlabial gap may be larger than normal or completely lacking (Burstone, 1967).

11.1.2.4 Chin

Both the skeletal and integumental chins become less retrognathic with progressive growth and development. The integumental chin tends to be closely related to the degree of prognathism of the underlying skeletal framework (Subtelny, 1959, 1961). A panel of judges rated the majority of subjects with horizontal growing mandibles, and thus "strong" chins, as being good looking (Lundström, Woodside and Popovich, 1987).

TABLE XLV

AGE RELATED CHANGES OF CEPHALOMETRIC PARAMETERS DESCRIBING SOFT TISSUE CHANGE

Lower lip to E-line Ricketts (1981):

AGE (years)	MEAN (mm)	S.D.
8	-1.25	N.A.
13	-2.50	
18 m	-3.75	
23 m	-5.00	

Holdaway H-angle (Bishara et al., 1984):

AGE (years)	MEAN (deg)	S.D.
5 m	15.0	3.9
f	14.5	5.0
10 m	13.6	3.8
f	13.8	5.1
15 m	13.2	4.8
f	10.5	5.6
25 m	8.1	5.5
f	9.1	6.0

Soft tissue profile (including nose) - Glabella-tip of nose-soft-pogonion (Bishara et al., 1984):

AGE (years)	MEAN (deg)	S.D.
5 m	147.4	3.4
f	148.0	4.2
10 m	144.3	3.6
f	143.2	4.7
15 m	139.2	4.4
f	139.8	6.0
25 m	140.2	4.9
f	138.9	6.2

Soft tissue profile (excluding the nose) - Glabella-soft-subnasale-soft-pogonion (Bishara et al., 1984):

AGE (years)	MEAN (deg)	S.D.
5 m	169.7	4.1
f	170.3	4.0
10 m	168.1	3.3
f	167.4	4.2
15 m	166.9	4.7
f	169.6	6.0
25 m	173.0	5.9
f	171.3	6.5

m = Male
f = Female
S.D. = Standard deviation
N.A. = Not available

Normal, or average, soft tissue dimensions for the parameters studied in the present investigation are not freely available. Nevertheless, two sets of measurements were found in the literature and have been presented for comparative purposes (Table XLV).

11.1.3 Soft tissue changes influencing the dentition

The dentition is not permanently fixed in relation to its skeletal base. Similarly the soft tissues overlying the teeth are not stable relative to the skeletal base of the denture. After approximately thirteen years of age they do, however, maintain a relatively fixed horizontal and vertical relationship to the denture itself. With these factors in mind, it seems reasonable to assume that the uprighting movements of the incisors, which are discussed in Chapter 8, result from functional relationships which exist between the dentition and the surrounding muscular forces. These functional relationships may become fully established before skeletal growth has been completed. A continuing downwards and forwards growth of the maxilla and mandible tends to create somewhat more protrusive skeletal bases for the teeth. Since the degree of growth expressed by the mandible exceeds that which occurs in the maxilla (Subtelny, 1959), this discrepancy in growth is evidenced by a decrease in the convexity of the skeletal profile.

In terms of functional objectives, it seems reasonable to position the teeth in such a position that minimal muscular activity is required to move the lips from a relaxed to a closed position. The ability to produce an adequate oral seal then becomes a functional objective of orthodontic therapy. The lower lip normally contributes more movement to effect oral closure than does the upper lip, as both lips simultaneously retrude and flatten against the incisors (Burstone, 1967).

The effect of vertical growth of the lips was also emphasized by Vig and Cohen (1979) who found that the lower lip is elevated during growth between the ages of ten and eleven years and that there is a reduction in the lip seperation.

11.1.4 The effect of orthodontic treatment on the soft tissue

It is most important to have a sound understanding of the changes which occur in the soft tissue profile during orthodontic treatment, concurrent with normal growth and development (Attarzadeh and Adenwalla, 1990).

11.1.4.1 Vertical changes

A predictable closure of the interlabial gap occurs when both horizontal and vertical movements of the maxillary incisors occur during retraction of the anterior teeth (Jacobs, 1978).

11.1.4.2 Lip thickness and strain

The placement of teeth according to accepted cephalometric criteria does not necessarily ensure that their overlying soft tissue will drape in a harmonious manner. Holdaway (1983, 1984) illustrates this with his soft tissue analysis. According to Holdaway's findings there is an upper lip to upper incisor ratio which has to be attained in order to achieve soft tissue balance at the end of treatment. This is true for growing subjects, but not so for adults and for subjects with either thin or thick lips. On average, however, there seems to be a significant correlation between osseous, and soft tissue changes in both males ($r = 0.83$, $p < 0.01$) and females ($r = 0.85$, $p < 0.01$) (Oliver, 1982).

11.1.4.3 Thickness of soft tissue over lips

Research done by of Holdaway (1983) indicates that for adolescents the normal thickness of the soft tissue at point A is 14 to 16 mm. When the position of point A is altered by tooth movement, the soft tissue overlying this landmark will follow the bone movement and remain at the same relative thickness. When there is tension and thinning of the upper lip, immediately anterior to the incisors, the tissues will thicken if the incisors are moved palatally. This will occur until the tissues approach their normal thickness over point A. When the lip tension has been eliminated, further palatal movement of the incisor will cause the lip to follow the incisors in a one to one ratio.

In some patients with lip tension and in whom the tissue thickness at point A is very thin, the lip may follow incisor retraction immediately and so retain a reduced thickness. If the tissue at point A is very thick the lip may not follow incisor retraction at all. In the adult the the lips will usually follow the teeth immediately even though there may be lip tension present.

11.1.4.4 Nasolabial angle

Changes in the nasolabial angle during orthodontic treatment were studied by Lo and Hunter (1982). They found that:

i) The nasolabial angle did not change significantly with growth.

ii) Increases in the nasolabial angle were significantly correlated with the amount of maxillary incisor retraction.

iii) Increases in lower facial height and/or the mandibular plane angle, during treatment, were accompanied by increases in the nasolabial angle.

iv) The response of the nasolabial angle in an extraction group was not significantly different from that found in a similar nonextraction group.

v) The observed changes in the soft tissue profiles were significantly correlated with changes in the underlying hard tissue landmarks for the period studied.

vi) No significant sexual dimorphism was noted in this study.

vii) The results of this study indicate that a significant portion of the soft tissue profile could be influenced by orthodontic treatment.

11.1.4.5 Hard tissue to soft tissue

Different workers have tried to show a relationship between hard and soft tissue alterations in the lip area. Some observed that successful orthodontic treatment did not consistently result in improved aesthetics (Brodie et al., 1938; Wylie, 1955). Others were of the opposite opinion (Angle, 1907; Tweed, 1954; Stoner et al., 1956).

Most authors agreed, however, that changes in the position of the incisors, especially retraction, alter the contour of the lips (Buchin, 1957; Ricketts, 1960; Bloom, 1961; Subtelny, 1961; Rudee, 1964; Branoff, 1971; Hershey, 1972; Anderson et al., 1973; Garner, 1974; Wisth, 1974; Huggins and McBride,1975; Forsberg and Odenrick, 1981; Oliver, 1982; Holdaway, 1984). Upper lip retraction was found to equal about 40 percent of the distance of a maxillary incisor retraction while the lower lip retraction equaled about 70 percent of the maxillary incisor retraction distance (Yogasowa, 1990).

There are, however, different opinions as to whether there is a definite correlation between treatment-induced incisor changes and soft tissue responses (Finnoy, Wisth and Boë, 1987). Some workers claim to have found such a relationship (Bloom, 1961; Rudee, 1964; Anderson et al., 1973; Huggins and McBride, 1975; Oliver, 1982; Holdaway, 1984), whereas others reported great individual differences (Branoff, 1971; Hershey, 1972; Wisth, 1974) and that the response was dependent on many different factors. These included the degree of incisor retraction, lip strain and morphology, age, sex, and type of treatment. Lower lip changes in response to orthodontic tooth movement were found to be more predictable than those brought about in the upper lip. The low degree of predictability which is associated with upper lip responses to orthodontic tooth movement may be caused by the complex anatomy and/or dynamics of the upper lip (Talass, Talass and Baker, 1987). When profile changes are compared to values representing "normal" facial aesthetics, it is evident that, in general, extraction of four first premolars does not result in a concave profile (Drobocky and Smith, 1989).

There is general agreement that orthodontic treatment can influence the soft tissue profile, but there is still disagreement on the exact amount of response of the soft tissues to changes in the positions of the teeth and/or alveolar processes (Finnoy, Wisth and Boë, 1987).

Some workers report that a definite correlation exist between incisor movement and soft tissue changes (Stoner et al., 1956; Riedel, 1957; Bloom, 1961; Rudee, 1964; Anderson et al., 1973; Garner, 1974; Roos, 1977; Koch et al., 1979; Oliver, 1982). Others, in contrast, have found that observed changes in the soft tissues do not follow changes in the dentition proportionately (Burstone, 1958; Neger and Newmark, 1959; Subtelny, 1961; Hershey, 1972; Angelle, 1973; Wisth, 1974).

These different responses in different individuals may be attributed to variation in gender (Huggins and McBride, 1975), variation in lip morphology (Oliver,1982; Holdaway, 1983), the amount of incisor retraction (Wisth, 1974), different treatment mechanics (Forsberg and Odenrick, 1981) or to extraction or nonextraction treatment regimes (Stromboni, 1979).

11.1.4.6 Lip changes

During treatment, the lower lip tends to increase slightly more in length with mesiocclusion (Class III) than it does with distocclusion (Class II). The measured changes were principally connected with growth and increased bite height. Following retraction of the upper teeth during treatment of Class II malocclusions, the lower lip "curls up" and moves forwards. During treatment of Class III malocclusion, the lower incisors tend to tip lingually and the lower lip tends to move lingually. Sublabially, lip contours behave in the same way as the roots of the lower incisors (Rakosi, 1982).

The upper lip became thicker during the treatment of Class II malocclusions and thinner during treatment of Class III malocclusions. The result was that differences in upper lip thickness, between the two types of malocclusion, ceased to be significant after treatment.

Lip tension needs to be considered when assessing the aesthetic prognosis and restoration of lip closure (Rakosi, 1982; Holdaway, 1983, 1984).

11.1.4.7 Orthognathic surgery

The reader is referred to the abundant descriptions of the various orthognathic surgical analyses and techniques which have a bearing on the soft tissue profile (Worms, Isaacson and Spiedel, 1976; Suckiel and Kohn, 1978; Proffit, Turvey and Moriaty, 1981; Kinnebrew, Hoffman and Carlton, 1983; White and Proffit, 1985; Wolford, Hilliard and Dugan, 1985).

11.1.4.8 Cephalometric standard

Park and Burstone (1986) tested the efficacy of cephalometric dentoskeletal standards, when used as clinical tools, to predict desirable facial aesthetics. They concluded that the chances of consistently producing desirable profiles by treating according to such a standards is questionable.

There are hundreds of measurements that may be used in tracing cephalometric head films (Steiner, 1960). Steiner cautioned, however, that orthodontists should not let the number of parameters which are measured become so complicated and unwieldy that they cease to be of practical use.

11.1.5 Lip strength and its effects on the dentition

Posen (1972) described a clinical method for measuring the strength of the lips with a pommeter. The rationale behind his procedure was the belief that the teeth are in a state of balance between forces which act on them from the labial and lingual sides. Although the importance of muscle forces, which result from normal oral functions has at times been questioned, it can not be denied that forces which originate from lips, cheeks and tongue may be important. It was Posen's belief that strong lips may indicate the presence of a high lip muscle tone and which could result in substantial labial forces acting on the front teeth. He found that subjects with Angle Class II division 2 malocclusion have an increased, and subjects with bimaxillary protrusion a decreased lip strength, when measured with his method. From a clinical point of view these findings seemed logical and measurements of lip strength could therefore be of importance in orthodontic treatment planning.

The concept which proposes that the teeth are in a state of equilibrium between all the muscle forces which act upon the dentition (Posen, 1972) has largely been rejected (Marx, 1965; Proffit, 1986). It is now recognized that forces, other than those which result from the facial muscles, have an effect on the positions of the teeth (Proffit 1986).

Marx (1965) found with his electromyographic study that the postural activity of lips is reduced in subjects with Class II division 2 malocclusions and concluded that the forces generated by lip activity is generally secondary to incisor position. The theory thus proposed by Posen (1972) that the upper incisor inclination in, for example, Class II division 2 malocclusions are due to an increase in lip force was already earlier disposed of by Marx (1965) with his electromyographic findings.

Simpson (1977) observed changes in muscle activity of the upper lip to be unrelated to the amount of upper incisor orthodontic retraction.

As a result of their studies Ingerval and Janson (1981) concluded that lip strength measurements have limited reproducibility and thus that the clinical value of lip strength measurement is limited to some degree.

11.1.6 Soft tissue analyses

Profilometric analyses, by means of a silhouette profile attained from photographs, were used to evaluate soft tissue profiles (Peck and Peck, 1970; Lines, Lines and Lines, 1978).

Various cephalometric soft tissue analyses are described in the literature (Rakosi, 1982). Included among these are proportional analyses, angular analyses, analysis of the thickness of soft tissue profile and the profile analysis of Schwarz.

The Moorrees mesh diagram graphically displays variations among facial components and thereby provides a description of facial morphology in a single step. A modification of the Moorrees mesh diagram takes advantage of linear and angular measurements which were added to the original analysis. This modification is particularly useful for planning surgical corrections of facial dysmorphology (Ghafari, 1987). A proportional assessment of both hard and soft tissue craniofacial relationship furnishes a valuable guide in orthodontic treatment planning (Carlotti and George, 1987).

Radiographic cephalometric analyses which use profile lines to evaluate the portion of the lips in relation to the face include the popular cephalometric analyses of Steiner (1953), Merrifield (1966), Ricketts (1981) and Holdaway (1983).

Lips lying behind the S-line of Steiner (1953) are too flat, while those lying anterior to it, are too prominent. The Z-line of Merrifield (1966) is based on the Frankfurt horizontal plane and gives a critical description of a number of lower facial relationships. Merrifield incorporated aspects of the Tweed (1966) triangle into his soft tissue analysis. In adults with normal Tweed triangle and ANB measurements, the average Z-angle is 80 degrees. In patients eleven to fifteen years of age with normal Tweed and ANB measurements, the average Z-angle is 78 degrees.

The soft tissue reference line used by Ricketts (1981) extends from the tip of the nose to soft tissue Pogonion. In average individuals the upper lip is 2-3 mm and the lower lip 1-2 mm behind this line.

The Holdaway soft tissue analysis (Holdaway, 1983), reflecting the relationships of 11 soft tissue paramaters, is clinically a very useful tool. It assists the orthodontist in his evaluation of the soft tissue profile, especially the important area of the lower face which is easily affected by orthodontic treatment.

The Ricketts E-line, the Steiner S-line and the soft tissue facial plane all seem to be equally acceptable as basis for assessment of the soft tissues of the profile (Saxby and Freer, 1985). A study of the reproducibility of these profile lines found that the S- and E-lines were almost equally reproducable and that they are less variable than the Holdaway H-line (Hillesund, Fjeld and Zachrisson, 1978). An additional finding of this study was that reproducibility is not definitely dependent upon whether or not the cephalograms were made in patients with open or closed lips.

Lip protrusion can be evaluated by relating the lips to a true vertical line passing through the soft tissue point A and through soft tissue point B. The lips should lie along or only slightly in front of this line. This evaluation should be carried out with the subject's lips relaxed. It is also important to note the extent to which the lips are separated when they are relaxed and whether the subject must strain to bring the lips together (Proffit, 1986).

Soft tissue parameters commonly used by orthodontists in their diagnosis and treatment planning, as well as in the evaluation of profile changes which occur as a result of growth and/or orthodontic treatment, were reviewed. The literature indicates that the various angles and lines used to evaluate the soft tissue profiles as previously noted do not all behave in a similar manner with age. Therefore, the clinicians need to use a series of soft tissue parameters in order to better evaluate soft tissue profiles (Holdaway, 1983; Bishara, Peterson and Bishara, 1984; Bishara, Hession and Peterson 1985).

11.1.7 Ethnic differences in soft tissue profile

When examining facial aesthetics clinicians should be aware of the implications of variation in ancestral heritage (Thomas, 1979).

Although it appears that no single cephalometric dentofacial or study cast parameter significantly correlates with post-treatment lower incisor crowding (Little, Wallen and

Riedel, 1981; Sinclair and Little, 1983, 1985; Shields, Little and Chapko, 1985) it may be postulated that certain, as yet not fully understood, aspects of soft tissue changes are able to influence the stability of an orthodontically treated dentition. A question also often asked is whether the findings of other researchers are applicable to our samples. It is thus imperative to encourage the comparison of similar studies, but on different samples and on different continents in order to enable researches to find the elusive answers in respect to long-term changes following orthodontic treatment.

11.2 Objectives

There exists no longitudinal data in respect to this or another similar sample (Table I). Soft tissue can influence the hard tissue and the opposite can also occur. Stability of the dentition following treatment can thus be influenced by the soft tissue changes occurring during and following treatment. It is thus essential to assess the changes occurring in one sample. The results should not be accepted as dogma, but it must be compared to other studies in order to establish whether direct comparison is valid and if differences exist, to point them out or if none exist, to be able to support the specific philosophy.

Hence, the objectives of this part of the study were:

i) to assess some longitudinal soft tissue changes in the orthodontically treated subjects of this sample.

ii) to correlate these changes with lower incisor irregularity in the same group.

11.3 Materials and methods

The basic description of the materials used and the methods employed to assess the data of this study are documented in Chapter 3 of this thesis.

Cephalometric measurements describing the soft tissue variables were obtained using the Oliceph computer programme. The Holdaway soft tissue analysis (Holdaway, 1983) requires the lips to be together. Hence, all the cephalograms were taken with the lips together. In the construction of a visual treatment objective, prediction of the changes in lip morphology is of great importance. A major factor is the vertical position of the lip embrasure and its relation to the incisal edges of the upper incisors. Lip mobility should thus be included in a clinical evaluation of the subject, especially when a short upper lip is present. The immobile upper lip can easily be assessed by taking two lateral cephalograms, one with lips closed and the other with relaxed lips as proposed by Steyn (1981). The Holdaway soft tissue analysis and visual treatment objective adapt for these situations (Holdaway, 1983, 1984). The following cephalometric measurements were used:

i) Nose prominence (Holdaway, 1983):
   Nose prominence measured from the tip of the nose to a line perpendicular to Frankfurt horizontal and running tangential to the vermilion border of the upper lip (NOSE-MM).

ii) Sulcus depth (Holdaway, 1983):

a) Superior sulcus depth measured from the deepest aspect of the concavity of the sulcus to a perpendicular to Frankfurt horizontal and tangential to the vermilion border of the upper lip (SUPSULD-MM).

b) Inferior sulcus depth measured from the deepest aspect of the concavity of the sulcus to the H-line (I-SULH-MM).

iii) Upper lip curl (Holdaway, 1983):

Measurement of soft tissue subnasale to the H-line (SAHLINE-MM).

iv) Lips to profile lines as described by:

a) Ricketts (1981). Lower lip to the E-plane (L-LIPE-MM).

b) Ricketts (1960). Upper lip to the E-plane (U-LIPE-MM).

c) Merrifield (1966). Angular measurement of the Z-line intersection with Frankfurt horizontal (Z-ANGLE-DEG). The Z-line is a line tangential to the most prominent lip which can be either upper or lower lip (the H-line in comparison is tangential to only the upper lip).

d) Holdaway (1983). Angular measurement of the H-line to the soft tissue Nasion-Pogonion line or soft tissue facial plane (H-ANGLE-DEG).

e) Holdaway (1983). Lower lip to the H-line (LLIPH-MM).

v) Lipstrain (Holdaway, 1983):

a) Basic upper lip thickness near the base of the alveolar process about 3mm below point A (ULIPTH-MM).

b) Upper lip thickness at the vermilion border with closed lips (ULIPTAP-MM).

c) Upper lip strain measurement produced as the difference between ULIPTH-MM and ULIPTAP-MM (ULIPSTR-MM).

vi) Soft tissue chin (Holdaway, 1983):

a) Soft tissue facial angle measured at the intersection of Frankfurt horizontal and the soft tissue facial plane (STFAC-DEG).

b) Soft tissue chin thickness (STCHIN-MM).

Only one metrical variable was assessed on the orthodontic study cast by means of digital calipers capable of measuring to 0.01 mm. Pre-treatment (T1), post-treatment (T2) and post-orthodontic (T3), lower incisor crowding were assessed according to the Little Irregularity Index (Little, 1975).

The data were subjected to descriptive statistics (mean and standard deviation), pairwise differences assessment (Friedman test) and Spearman correlation coefficient tests for each of the three time intervals (T1, T2 and T3) (Zar, 1984). The significance level of this part of the study was set at 0.05.

11.4 Results

The results are set out in Tables XLVI and XLVII.

The purpose of the measurements in this part of the study was to assess possible longitudinal soft tissue changes as a result of the orthodontic treatment. Correlations of the changes in the soft tissue parameters studied with the post-orthodontic (T3) Little Irregularity Index (Little, 1975) indicated the occurence of a relationship between the recorded soft tissue changes and the stability of the orthodontically treated dentitions.

The variables which were not significantly ($p > 0.05$) changed during treatment (T1-T2) were the inferior sulcus depth (I-SULH-MM), lower lip to H-line (LLIPH-MM), soft tissue facial angle (STFAC-DEG) and soft tissue chin thickness (STCHIN-MM) (Table XLVI).

Variables which changed significantly ($p < 0.05$) during the post-orthodontic interval (T2-T3) were nose prominence (NOSE-MM), inferior sulcus depth (I-SULH-MM), upper lip to E-line (U-LIPE-MM), lower lip to E-line (L-LIPE-MM), Merrifield Z-angle (Z-ANGLE-DEG), lower lip to H-line (LLIPH-MM), upper lip strain (ULIPSTR-MM), soft tissue facial angle (STFAC-DEG), soft tissue chin thickness (STCHIN-MM) and the Little Irregularity Index (L-IRREG) (Table XLVI).

Some of the variables showed a significant change when assessment was done for the total evaluation period (T1-T3), but not during the post-orthodontic interval. They included the superior sulcus depth (SUPSULD-MM), upper lip curl (SAHLINE-MM), Holdaway H-angle (H-ANGLE-DEG), upper lip thickness near the base of the alveolar process (ULIPTH-MM) and upper lip thickness at the vermilion border (ULIPTAP-MM) (Table XLVI).

The Spearman Correlation Coefficients, set out in Table XLVII, showed only a few weak, significant relationships between the variables measured and the post-orthodontic (T3) lower incisor irregularity. The infer sulcus depth (I-SULH-MM) (r = -0.42. p = 0.0001) and lower lip to H-line (LLIPH-MM) (r = 0.31, p = 0.003) correlated significantly at the pre-treatment period (T1) and the Z-angle (Z-ANGLE-DEG) (r = -0.24, p = 0.02) and soft tissue facial angle (STFAC-DEG) (r = -0.27, p = 0.01) showed similar results at the final observation (T3).

11.5 Discussion

Soft tissue changes occur not only as part of a normal physiologic process, but also during and following orthodontic treatment. These changes are important when the stability of the occlusion following orthodontic treatment is at stake.

Numerous attempts have been made to assess the influence of muscle function on the dentition (Marx, 1965; Posen, 1972; Simpson, 1977; Ingerval and Janson, 1981). The clinical value of these results appear to be limited (Ingerval and Janson, 1981). The influence of the soft tissues surrounding

TABLE XLVI

DESCRIPTIVE STATISTICS FOR METRICAL DATA IN RESPECT OF THE SOFT TISSUE (Friedman test included)

	T1		T2		T3			T1-T2	T1-T3	T2-T3
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.	p-value	Pairwise	Differences	
NOSE-MM	13.14	1.96	15.93	2.11	18.04	2.35	0.0001	-	-	-
SUPSULD-MM	-9.79	2.98	-8.96	2.80	-8.27	3.19	0.0001	-	-	x
I-SULH-MM	5.02	2.35	4.84	1.91	5.45	2.30	0.02	x	x	-
SAHLINE-MM	6.74	2.21	4.82	1.70	4.73	1.72	0.0001	+	+	x
U-LIPE-MM	-0.93	2.39	-4.14	1.91	-5.86	2.36	0.0001	+	+	+
L-LIPE-MM	0.49	3.07	-2.13	2.09	-3.69	2.61	0.0001	+	+	+
Z-ANGLE-DEG	69.55	7.49	74.80	5.99	76.85	10.57	0.0001	-	-	-
H-ANGLE-DEG	16.98	3.85	13.59	3.14	12.35	3.65	0.0001	+	+	x
LLIPH-MM	1.13	2.19	0.69	1.46	0.34	1.67	0.0002	x	+	+
ULIPTH-MM	14.73	1.52	15.95	2.06	16.48	2.16	0.0001	-	-	x
ULIPTAP-MM	11.48	2.14	13.49	1.99	13.56	2.53	0.0001	-	-	x
ULIPSTR-MM	3.25	1.98	2.46	1.65	2.92	2.01	0.0002	+	x	-
STFAC-DEG	89.09	3.28	89.71	3.62	90.98	3.58	0.0001	x	-	-
STCHIN-MM	10.13	2.13	10.47	2.05	11.29	2.43	0.002	x	-	-
L-IRREG	4.21	3.57	0.43	0.66	1.71	1.64	0.0001	+	+	-

S.D. = Standard deviation
+ = Significant, $p < 0.05$ (T1 > T2, T3)
- = Significant, $p < 0.05$ (T1 < T2, T3)
x = Not significant, $p > 0.05$

TABLE XLVII

SPEARMAN CORRELATION COEFFICIENTS COMPARING THE RELATIONSHIP OF THE LOWER INCISOR IRREGULARITY AT T3 AGAINST THE MEASURED VARIABLES AT T1, T2 AND T3

L-IRREG

	T1		T2		T3	
VARIABLE	r	p	r	p	r	p
NOSE-MM	-0.02	0.84	0.02	0.82	-0.09	0.39
SUPSULD-MM	0.03	0.78	-0.12	0.26	-0.12	0.27
I-SULH-MM	-0.42	0.0001	-0.06	0.60	0.12	0.26
SAHLINE-MM	-0.13	0.24	0.14	0.19	0.11	0.32
U-LIPE-MM	0.16	0.14	0.12	0.27	0.20	0.06
L-LIPE-MM	-0.10	0.34	0.10	0.38	0.12	0.25
Z-ANGLE-DEG	-0.10	0.35	-0.15	0.15	-0.24	0.02
H-ANGLE-DEG	-0.16	0.15	0.18	0.10	0.17	0.12
LLIPH-MM	0.31	0.003	0.10	0.44	-0.01	0.92
ULIPTH-MM	-0.05	0.64	-0.01	0.91	0.13	0.24
ULIPTAP-MM	-0.04	0.74	0.11	0.33	0.10	0.34
ULIPSTR-MM	-0.01	0.94	-0.16	0.14	0.10	0.43
STFAC-DEG	-0.19	0.07	-0.06	0.56	-0.27	0.01
STCHIN-MM	0.03	0.78	-0.02	0.86	-0.12	0.29

r = Spearman Correlation Coefficient
p = Probability value, significance level 0.05

the dentition, however, can not be underestimated. Significant changes were measured in the soft tissue during the post-orthodontic period (T2-T3) and cognizance must be taken of the significant correlations shown with late lower incisor irregularity (Table XLVII).

The concept of continued growth following puberty was reported by Behrents (1984). This continued growth as recorded during the post-orthodontic period (T2-T3) (Table XLVI) plays its part in influencing tooth position. Behrents (1984) noted similar findings during adulthood and stated that growth changes take place in the environment created by the normal function of facial muscles.

In the present study cephalometric soft tissue analyses were used to assess the longitudinal changes which occur during and following orthodontic treatment (Merrifield, 1966; Ricketts, 1981; Holdaway, 1983). The observed changes were subsequently correlated to lower incisor irregularity (Little, 1975).

All the variables measured, except the inferior sulcus depth (I-SULH-MM), lower lip to H-line (LLIPTH-MM), soft tissue facial angle (STFAC-DEG) and soft tissue chin thickness (STCHIN-MM) showed significant changes from the pre-treatment to end of treatment observations (T1-T2) (Table XLVI). The changes were expected as the lips change as a result of the better tooth positions attained at the end of active treatment (T2). A similar finding was also, amongst others, reported by Finnoy, Wisth and Boë (1987).

The mean increase in nose prominence (NOSE-MM), which was significant at all three observations ($p = 0.0001$), was 2.79 mm (T1-T2) and 2.81 mm (T2-T3). The mean anterior positioning of the chin (STFAC-DEG) was 0.62 degrees (T1-T2) ($p > 0.05$) and 2.27 degrees (T2-T3) ($p = 0.0001$). The increase in soft tissue chin thickness was 0.34 mm (T1-T2) ($p > 0.05$) and 0.82 mm (T2-T3) ($p = 0.002$) (Table XLVI). These three parameters measured mainly growth related changes and thus not within the control of the clinician.

The values of the variables at the end of treatment (T2) (Table XLVI) are within the clinically accepted norms described by Merrifield (1966), Little (1975), Ricketts (1981) and Holdaway (1983), except for upper lip strain which should have been closer to 1.00 mm (Holdaway, 1983) than the 2.46 mm mean value recorded and the upper lip being further retruded from the E-line (4.14 to 0.7 mm). The lips become more retrusive with age (Table XLV), but the upper lip strain, which was not entirely eliminated during treatment, possibly contributed to the upper lip being flatter in relation to the E-line. The mean value for lower incisor inclination (Chapter 7), was at the maximum end of the described norms (proclined) at the end of treatment (T2). If the lower incisor is not sufficiently uprighted (Tweed, 1962), the upper incisors cannot be entirely retracted into their ideal position. This phenomenon could also explain why the upper lip strain was not entirely reduced during the treatment (T1-T2).

When evaluating the overview of changes which took place from the pre-treatment to the final observation (T1-T3) it will be observed that there were only two which showed non-significant changes. The non-significant ($p > 0.05$) changes are inferior sulcus depth (I-SULH-MM) which increased by a mean value of 0.43 mm and upper lip strain (ULIPSTR-MM) which decreased by a mean value of 0.33 mm (Table XLVI). The upper lip strain, however, significantly increased during the post-orthodontic period (T2-T3) ($p = 0.0002$). This slight increase could indicate clinically significant anterior movement of the dentition (Moyers, 1988). Previously reported changes such as the lips becoming less protrusive in respect to the tip of the nose and soft tissue chin (lower soft tissue profile), as well as the total soft tissue profile increasing in convexity (Table XLV) were all observed during this longitudinal study (Table XLVI). The total soft tissue profile is especially influenced by the elongation of the nose during growth.

The most important phase of the study was the evaluation of changes which occurred from the end of treatment to the final observation (T2-T3). Such changes could have a major influence on the stability of a treated dentition. The Little Irregularity Index (Little, 1975) was significantly improved from T1 to T2 (4.21 mm to 0.43 mm) (Table XLVI). It did, however, significantly ($p = 0.0001$) increase again during the post-orthodontic phase (T2-T3) (0.43 mm to 1.71 mm). Although these mean values indicate an increase in lower incisor irregularity, the mean final crowding was well within clinically accepted norms (Little, 1975) or in other words, not clinically significant. The significant soft tissue changes which occurred during this period of evaluation were, a continued increase in nose prominence, a deepening of the lower lip sulcus, the lips becoming more retrusive to the profile lines, the upper lip strain increased, the soft tissue Pogonion moved forward and the soft tissue chin thickness increased slightly. All of these changes could be ascribed to those normal maturational changes which are a part of ageing (Behrents, 1984). The measured variables even though changing, remained within the accepted norms as described in the literature (Merrifield, 1966; Little, 1975; Ricketts, 1981; Holdaway, 1983). The inferior lip sulcus depth (I-SULH-MM) which did not show any significant change during the treatment (T1-T2) and in general from T1 to T3, did increase significantly (p = 0.02) by a mean value of 0.61 mm during the post-orthodontic phase (T2-T3) (Table XLVI). A slight, but significant increase in incisor overjet (mean 2.85 mm to 3.17 mm) (Chapter 8) could have contributed to this deepening of the lower lip sulcus as a result of upper incisor pressure on the lower lip. The observed uprighting of the lower incisor (Chapter 8) could have complimented the increase in the depth of the lower lip sulcus.

The visual treatment objective (V.T.O.) is a useful tool when used as an adjunct to the other orthodontic study records (Ricketts et al., 1979; Holdaway, 1984) . This is true especially when assessing the predicted results at the end of treatment (T2). Holdaway (1984) describes certain goals which can be achieved if the soft tissue changes are planned according to his V.T.O. One of the guidelines suggested by holdaway (1984) is to determine the future lip position (lip profile) according to the H-angle and it's relationship with the point A convexity (Chapter 4). The H-angle should be 10 degrees plus the measured value of the point A covexity (Holdaway, 1984). This goal was achieved during the study. The noted value of this relationship was within clinically acceptable norms achieved at the final observation (T3) (H-angle = 12.35 +/- 3.65 degrees, Table XLVI; Point A convexity = 1.12 +/- 2.99 mm, Table XIX).

Significant correlations of the measured soft tissue variables with the post-orthodontic lower incisor irregularity are portrayed in Table XLVII. These were the inferior sulcus depth (I-SULH-MM) and lower lip to H-line (LLIPH-MM) at the pre-treatment observation (T1) and the Z-angle (Z-ANGLE-DEG) and soft tissue facial angle (STFAC-DEG) at the final observation (T3) which showed weak significant ($p < 0.05$) correlations with lower incisor irregularity (r = -0.42, 0.31, -0.24 and -0.27 respectively). It is, however, an indication that lip profile (Z-ANGLE-DEG) and mandibular growth (STFAC-DEG) change can influence incisor position following orthodontic treatment.

Facial biologists appreciate that a relapse of the occlusion following orthodontic treatment is a normal reaction of the growth process itself, and that it serves to restore morphology in a manner that protects against incursions disturbing functional and morphologic balance, either during or subsequent to the childhood growth period. Behrents (1984) referred to these post-pubertal maturity changes as growth in the adult. Either a new composite balance is achieved or, likely, some degree of rebound occurs because of the aggregate influence exerted by the composite of all regional growth fields (Enlow, 1986).

The soft tissue growth and maturational changes measured in the present study, which the orthodontists have no control over whatsoever, could have influenced the increase in the lower incisor irregularity during the post-treatment interval.

11.6 Conclusions

1. Mainly growth and maturational changes occur in the soft tissue post-treatment. These changes could influence the stability of the treated occlusion.
2. No strong significant correlations could be shown between the observed soft tissue changes and lower incisor irregularity. The Merrifield Z-angle and Holdaway soft tissue facial angle (chin prominence) did, however, show weak significant associations with post-treatment lower incisor irregularity.
3. Protrusive lower lips influence the lower lip sulcus depth. Both variables showed moderate correlations with pre-treatment lower incisor irregularity.
4. The Holdaway H-angle and the point A convexity relationship as used for the Holdaway soft tissue visual treatment objective (Holdaway, 1984) is supported by the

long-term data of the present study and must be taken in consideration when prospectively planning orthodontic treatment.

5. The mean lower incisor irregularity increase which followed orthodontic treatment can be partly attributed to soft tissue growth changes. The prerequisite when making this assumption, however, is that clinical acceptable norms be the order of the day at the end of active treatment.

CHAPTER 12

SEXUAL DIMORPHISM AND ITS RELATIONSHIP WITH POST-ORTHODONTIC LOWER INCISOR IRREGULARITY

12.1 Introduction

Growth, which does not occur uniformly, results in increases in size of the dento-facial complex. Growth also includes differential and proportional changes (Hellman, 1927a, 1927b; Krogman, 1939). Sexual differences observed during growth in orthodontic patients include the more prognathic mandible of females when compared with male subjects of the same age (Hellman, 1932). In terms of Hellman's dental age, girls attain their pubescent growth about one dental age ahead of boys (Krogman, 1951). Growth tends to continue in boys after it has ceased in girls (Hellman, 1935; Krogman, 1951).

Studies on morphological changes of the craniofacial skeleton and soft tissues are numerous (Behrents, 1984). For most part these studies can be historically dated as before or following the invention and utilization of the cephalometric technique which was introduced by Broadbent (1931) and Hofrath (1931).

Prior to the development of the cephalometer, most studies were cross-sectional in nature dealing with measurements on dry skulls or cadavers, casual observations or gross body measurements on living individuals. After the advent of the cephalometer, precisely controlled longitudinal cephalometric studies became possible on living, growing individuals (Behrents, 1984).

There are generally recognized structural and proportional differences between young and mature faces and between male and female faces (Baum, 1961).

During a comparison of the skeletal and dental patterns of a group of children (7 to 9 years of age), with excellent occlusions, with those of an older group (11 to 13 years of age) various differences were noted. Boy's over-all facial patterns are essentially the same except for increases in size. The facial patterns of the girls are significantly different between the younger and older age groups, with older subjects showing less convex faces, more upright incisors, increases in facial size and higher facial angles. In both groups the mandibles appear to have larger dimensions than the maxilla (Baird, 1952). Barnes (1954) studied a group of children with excellent occlusions from twelve to fifteen years of age. His findings show that boys exhibit a significant increase in linear length of the maxilla and mandible. Girls show no increase in maxillary length, but the increase in mandibular length observed, results in less convex faces in the female group. The skeletal patterns oi both male and female faces also change in positional relationship, the mandibles becoming increasingly more protrusive and the profiles less convex. The boys in this age range develop less protrusive dentitions as a result of the maxillary incisors becoming more upright. No such change occur in the dental pattern of the girls.

Total facial height, as measured in a cross-sectional study, increases initially in males and females (Wunsche, 1953). Males show increases in the order of 1.1 mm from twenty to approximately forty years of age and decreases amounting to 2.4 mm after sixty years of age. Females reach their greatest facial height in the age group 26-30 years, and it subsequently starts to decrease thereafter to the extent of 7.7 mm after 71 years (Wunsche, 1953). Significant increases of head width and height is noted in females with a tendency for increases in males in a cross-sectional study of two Mexican adult populations (Lasker, 1953).

Males appear to be larger than females. Although this is noted, sex differences become less significant as the age level of the subjects increase. The maximal growth period of girls appear to be between eight and thirteen years of age and seem to start earlier and to be of a shorter duration than that of boys, whose maximal growth period is between thirteen and eighteen years of age (Seal, 1957). A study involving 100 males and 100 females (twenty to thirty years of age) with Class I occlusions show that male dimensions are larger than female dimensions except for the gonial angle. The sexual dimorphism in size and relationships of the facial components tend to increase with age (Horowitz and Thompson, 1964). The findings of an anthropometric study, including 87 male and 77 female Swedes ages twenty-five to forty-nine, of the head and the face (Lewin and Hedegard, 1970), show that males are larger than females.

Cross-sectional studies have some inherent limitations. They often demonstrate those factors which are not true, but can offer little in the way of clarifying or providing information as to what is actually occurring. These studies do, however, point out the features worth pursuing through subsequent longitudinal assessment.

The introduction of roentgenographic cephalometrics (Broadbent, 1931), allowed for longitudinal studies to be performed. This resulted in the development of a series of diagrams (Broadbent, 1937) illustrating an orderly, consistent growth pattern. The straight-line path of landmark migration for ages one to eighteen years of age is available in published format as the Bolton standards for males and females (Broadbent, Broadbent and Golden, 1975). The results of a serial study of the human male head from the third month to eight years showed little change in the development behaviour of the mean pattern, although considerable individual variation was found. Enlargement of the various anatomic areas occurs in a proportional manner. After an early age the nasal floor, occlusal plane, and the lower border of the mandible all retain stable angular relationships during growth and development. No change occur in the gonial angle, and no growth spurts are evident in these areas (Brodie, 1941). Realising that individual variations need to be pointed out, the era of cephalometric analyses started (Wylie, 1944; Downs, 1948; Steiner, 1953; Tweed, 1954; Ricketts, 1981; Holdaway, 1983).

A longitudinal cephalometric study performed on males and females in their twenties at initial examination and then re-examined at five years and ten years later, indicates a size difference between the sexes, but no sexual dimorphism is observed in regard to the degree of prognathism and inclination of the incisors (Forsberg, 1979). Forsberg (1979) finds no anteroposterior change in jaw relations for men, but a more retrognathic mandibular position is shown for the female group. Uprighting of the incisors is noted, which Forsberg (1979) believes to be the result of posterior mandibular rotation. This rotation of the mandible enlarges the lower facial height (0.35 mm in age group 24 to 29 years). No significant uprighting of the lower incisors is observed in a longitudinal study of 243 Swedish males (twelve to twenty years of age) (Björk and Palling, 1955). Earlier studies on the human head by Björk (1947), males after seven years, and Brodie (1941), ages prior to seven years, show increases in mandibular prognathism. The mandible shows greater prognathism than the maxilla, but both increase in prognathism which is characteristic of profile changes with age (Björk, 1947). Lande (1952) also supports this finding as shown in his study of a male sample (four to seventeen years of age). Lande (1952) shows the mandible becoming more prognathic in relation to both

Nasion and the maxilla and in this way decreasing the skeletal convexity. The skeletal patterns of a group including boys (twelve to nineteen years of age) and girls (twelve to eighteen years of age), with excellent occlusions, echoes these results (Meinhold, 1957). These changes occur faster in boys than girls (Schultz, 1955).

The mandible in its forward movement, which normally occurs at a greater rate than in the maxilla, causes the facial angle to increase from 82 degrees to 88 degrees and thus decreases the angle of convexity from +10 degrees to 0 degrees. Vertical growth is also greater in the posterior facial area (area of the ramus) than in the anterior facial area (at the profile), thus decreasing the mandibular plane angle from 28 degrees to 22 degrees. Accordingly, Gnathion may move downward and forwards along the Y-axis as much as 1/2 inch and may thus change the Y-axis several degrees (Downs, 1956) and at the same time cause an increase in the facial angle (Lundell, 1955). Similar obsevations are reported with Gnathion moving down the facial axis between 2.5 mm to 3 mm per year during growth of the mandible (Ricketts, et al., 1979; Holdaway, 1984). It is also noted that the face lengthens in vertical height in the later age groups (Björk, 1947). A longitudinal study of a group of nineteen boys between the ages of eight years to seventeen years and beyond, shows that the late stages of growth are accompanied by a continuation of forwards and downwards movement of the Anterior Nasal Spine and of Pogonion, while the dental arch and its supporting bone tend to move more slowly and thus to drop behind (Brodie, 1953). The prominence of the dentition subsequently decreases (Schaeffer, 1949; Brodie, 1953). This fact that the incisal edges and the labial surfaces of lower incisors from typical mandibles, when superimposed with orientation at Menton, became more retrusive in relation to the chin point is also supported by other studies including female and male subjects (Davis, 1956).

Subtelny (1959) studied the profile characteristics of soft tissue facial structures and their relationship to underlying skeletal structures. The long-term cephalometric parameters of thirty subjects with normal profiles, equally divided as to sex, and recorded at intervals of from three months to eighteen years of age show the following findings:

i) At eighteen years of age there are no striking differences in soft tissues or skeletal mandibular prognathism between boys and girls. At seven to eight years of age the boys, however, show only one-half the amount of prognathism that they would achieve by eighteen years of age, while the girls have already expressed three-fourths or more of the amount that they will achieve by eighteen years of age.

ii) In both sexes the skeletal profile tends to become less convex with each increment in age.

iii) The prominence of the nose tends to increase in comparison with the millimetre increments at the chin and the frontal prominence. No sex differences are, however, recorded. It is noted with reference to this lack of sex differences that con-comitant sex-differential increments at chin point, which are expected at this age, mask sex differences in forward growth at the tip of the nose, when assessed by the angle of convexity.

iv) The pattern of nose growth and the location of the tip of the nose, when studied by linear measurements, vary between boys and girls at certain ages. In twelve of fifteen boys a growth spurt is described which seems to centre around the thirteen and fourteen year old subjects. A similar spurt is evident in only three of fifteen girls and is observed to centre around twelve years of age.

v) Both mandibular and maxillary dentitions become less protrusive with increasing age.

A decrease in the angle of the maxillary incisor is a common change observed in females and males. In girls, however, the interincisal angle increases significantly (Lundell, 1955). Crowding of the incisors, loss of arch length, an increase in the interincisal angle and "normally" changing facial relationships occur in both sexes (Humerfelt and Slagsvold, 1972).

A comparison of the facial and dental patterns of a group of thirty-one boys and thirty-one girls (Baum, 1951) with those of young adults appraised by Downs (1948) in an earlier study shows that the face of the eleven to fourteen year old child, with excellent occlusion, does not present the same proportions as the face of the young adult. In general, the younger person has a more convex face, less upright incisors, and a more protrusive dentition. It is thus obvious that the dentofacial pattern changes with maturation. During this age range the female facial pattern becomes significantly less convex (more similar to the adult face) than the male facial pattern. The girl between eleven and fourteen years of age is thus closer to having achieved an adult dentofacial relationship than the boy, and therefore she has less post-pubertal growth potential (Baum, 1951). The facial and dental patterns of 12-year-old boys and girls when compared to those of adult men and women show that the facial patterns of boys are significantly different from those of men, but the facial patterns of girls are not significantly different from those of grown women except in size (Petraitis, 1951). Females show consistent minimum facial changes in size and proportion after fourteen to fifteen years of age. Males, on the other hand, consistently continue their growth and development until twenty years of age (Downs, 1956; Meinhold, 1957). Van Rensburg (1981) notes that male mandibles can increase in dimension late into the twenties. These findings are also observed in a study of 100 Caucasian children between the ages of eleven and twenty years, equally divided as to sex, showing strong correlations between the incremental changes at glabella and at the mandibular symphysis (Lavin, 1958). He shows that these changes are common in boys during the entire period of his study, but are less pronounced in girls of whom the majority show no change after the age of fifteen years (Lavin, 1958).

Females show facial growth changes which continue late into the second decade and males exhibit similar changes into their third decade of life (Hunter, 1966). Concerning these late growth changes, a study by Baer (1956) illustrates changes in the facial dimensions of 5,600 men and 7,420 women during the third decade of life. Baer (1956) demonstrates significant increases in facial height, nose height, and bizygomatic width in the men, but no such increases are shown in the women. A longitudinal study of subjects originally included in the Bolton growth study and later re-examined shows that growth changes of the craniofacial skeleton continues into old age in an apparent adaptive, but decelerating manner for both males and females (Behrents, 1984). Females are smaller, grow less and show a more vertical facial growth direction than males at all ages (Behrents, 1984).

Several other long-term studies have been reported in which the generalized normal growth of the craniofacial complex is described for males and females. Of the most popular are the Burlington growth study in Toronto (Popovich, 1955), the Michigan studies at Ann Arbor, Michigan (Riolo et al., 1974; Moyers et al., 1976), the Bolton study in Cleveland, Ohio (Broadbent et al., 1975) and the implant studies by Björk and Skieller (1983).

Age and sex are significant factors for orthodontists to consider in formulating a treatment plan in which growth is to play an important part. Orthodontists find themselves able to alter facial conformation to some considerable extent (Herzberg, 1952; Tweed, 1954; Ricketts et al., 1979; Holdaway, 1983, 1984; Proffit, 1986; Moyers, 1988). Appliance systems have been devised by which the orthodontist can control normal, progressive facial alterations as a part of the routine treatment procedure in correction of abnormal or unpleasant facial contours (Klein, 1957; Tweed, 1966; Graber, 1977; Frankel, 1980; Haas, 1980; Graber and Swain, 1985; Teuscher, 1986; Woodside, Metaxas and Altuna, 1987; Bass, 1990; McNamara, Howe and Dischinger, 1990).

In summary, there is apparently a well-ordered and predictable pattern in the dentofacial changes that accompany growth and development. A period which might be called the period of primary growth or growth in which sex is not a variable is followed by a period during which the adult pattern begins to assert itself. This second period might be called the period of developmental growth, since it involves both increase in size and progress toward maturity. The developmental growth period is sex and time linked, beginnig and ending earlier in girls than in boys and probably progressing further in boys. The progressive development of the adult complex has certain general characteristics which Baum (1961) describes as follows: The adult dentofacial relationship differs from that of the child in that the adult has a less convex face, a more protrusive dentition with more upright incisors, and a more prognathic mandible. In the male, these effects appear

TABLE XLVIII

SEXUAL DIMORPHISM IN CRANIOFACIAL PATTERNS
(Adapted from Broadbent et al., 1975)

VARIABLE	FEMALE	MALE
GENERAL:		
Circumpubertal growth spurt	10-12 years	12-14 years
Mature size	14-16 years	18 years
PHYSICAL CHARACTERISTICS: (differences develop in middle to late adolescence)		
Supraorbital ridges	Virtually absent	Well developed
Frontal sinuses	Small	Large
Nose	Moderate	More massive
Zygomatic prominences (cheekbones)	Small	Large
Mandibular symphysis (Pogonion)	Rounded	Prominent
External mandibular angle (Gonion)	Rounded	Prominent lipping
Occipital condyles	Small	Large
Mastoid processes	Small and delicate	Large
Occipital protuberance (Inion)	Insignificant	Prominent

* These dissimilarities were not significantly related to skeletal balance or malocclusion.

late, continue longer, and produce more marked changes resulting in a "three-L" postulate being formulated stating that boys grow later, longer and larger (Baum, 1961).

A tabulated adaptation from Broadbent et al. (1975) clearly illustrates the sexual dimorphism in craniofacial patterns (Table XLVIII). These differences are not correlated with skeletal balance or malocclusion (Sinclair and Little, 1983, 1985).

Sexual dimorphism is an important factor to evaluate in the search for post-orthodontic stability, especially when the active treatment is completed before facial growth and proportional change have ceased.

12.2 Objectives

The literature presents the orthodontist with results from pooled studies and from studies where the sexes are separated. When comparing data of different studies or when the presentation of new data is made, both types of assessments must be kept in mind. The differences between sexes can be ideally evaluated using longitudinal data. There exists no such information in respect to the present sample (Table I) or other equivalent samples.

Hence, the objectives of this part of the present study were to:

i) assess the long-term changes between males and females during and following active orthodontic treatment.

ii) test whether a relationship exists between sexual dimorphism and post-orthodontic lower incisor crowding.

12.3 Materials and methods

Eighty-eight Caucasian subjects (33 males and 55 females) were longitudinally assessed in respect of relapse of their dentitions following orthodontic treatment. The malocclusions were treated using conventional edgewise mechanics. The sample is set out in Table I.

The basic materials used and methods employed in order to assess the changes which occurred during the pre-treatment (T1), post-treatment (T2) and post-orthodontic (T3) periods were described in Chapter 3 of this thesis.

Orthodontic study casts and lateral cephalograms were analysed for all three stages studied. Intra-observer error was tested analysing a random repetition of measurments using the Wilcoxon test (Chapter 3).

The study casts were measured with digital calipers capable of measuring to 0.01mm as was previously described.

Cephalometric measurements were obtained with the use of the Oliceph computer program (Chapter 3).

The measurements of the various parameters have been described in the preceeding chapters.

The data (male versus female) were subjected to descriptive statistics such as mean and standard deviation for each of the three evaluations. The Wilcoxon and the Chi-square tests tested for significant differences between the groups at the three time intervals (Zar, 1984). The significance level of this part of the study was set at 0.05.

12.4 Results

The findings are set out in Tables XLIX, L, LI, LII, LIII, LIV and LV.

There was no significant ($p > 0.05$) difference in the ages between females and males at the three time intervals (Table XLIX).

The mandibular variables showing significant ($p < 0.05$) sexual dimorphism at the pre-treatment observation (T1) were the aggregate of the cranial base deflection, articular angle and the gonial angle (SUMANGLE: $p = 0.03$), the vertical deviation of the corpus of the mandible (CORSLING: $p = 0.01$), the arch length (ARCHL: $p = 0.05$ and LITTLE-A: $p = 0.0002$), the lower incisal edge position relative to the APo-line (I-APO-MM: $p = 0.04$) and the mandibular growth direction (GOGN-SN: $p = 0.01$ and FMA: $p = 0.01$) (Table L). The significant differences between males and females at the end of treatment (T2) were the mandibular length (GOGN-MM: $p = 0.02$ and GOGC-MM: $p = 0.004$), the articular angle (ARTANGLE: $p = 0.01$), the ramus height (RAMH-MM: $p =$ 001), the arch lehgth (ARCHL: $p = 0.001$ and LITTLE-A: $p =$

0.0001) and the mandibular growth direction (GOGN-SN; p = 0.03, FMA: p = 0.04 and FAC-TAPE: p = 0.02). At the final observation (T3) the following variables showed significant differences, being the mandibular length (GOGN-MM: p = 0.0001 and GOGC-MM: p = 0.0001), the ratio between the anterior and posterior mandibular lengths (GOGN-GOCO: p = 0.004), the articular angle (ARTANGLE: p = 0.03), the gonial angle (GONANGLE: p = 0.04), the aggregate of the cranial deflection, articular angle and the gonial angle (SUMANGLE: p = 0.002), the vertical deviation of the corpus of the mandible (CORSLING: p = 0.01), the ramus height (RAMH-MM: p = 0.0001), the corpus length (CORL-MM: p = 0.0001), the arch length (ARCHL: p = 0.01 and LITTLE-A: p = 0.0003), the lower incisor irregularity (L-IRREG: p = 0.02), the lower incisor position measured to the NB-line (I-NB-DEG: p = 0.04) and the mandibular growth direction (GOGN-SN: p = 0.0004, FMA: p = 0.001, FAC-AXIS: p = 0.03 and FAC-TAPE: p = 0.001) (Tables L).

<u>Maxillary variables</u> showing significant sexual dimorphism at the pre-treatment observation (T1) were the posterior cranial base length (SAR-MM; p = 0.02) and the upper first bimolar width (U6-6I: p = 0.02 and U6-6B: p = 0.002); at the end of treatment (T2) were the cranial base deflection (SADANGLE: p = 0.05), the anterior cranial base length (SN-MM; p = 0.001), the posterior cranial base length (SAR-MM : p = 0.001) and the upper first bimolar width (U6-6I: p = 0.0001 and U6-6B; p = 0.0001); at the post-orthodontic observation (T3) were the point A convexity (A-CONVEX: p = 0.01), the cranial base length

TABLE XLIX

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS FOR AGE VARIABLE

VARIABLE		MALE		FEMALE		
		MEAN	S.D.	MEAN	S.D.	p
AGE	T1	11.77	1.06	12.00	1.12	0.29
	T2	15.15	2.42	14.49	1.15	0.17
	T3	21.96	3.94	21.18	3.21	0.46

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
S.D. = Standard deviation

TABLE L

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS FOR A NUMBER OF MANDIBULAR VARIABLES

VARIABLE		MALE		FEMALE		
		MEAN	S.D.	MEAN	S.D.	p
MANDIBLE-DIMENSIONS:						
SNB	T1	76.82	2.96	76.80	3.58	0.35
	T2	76.51	3.17	76.49	3.60	0.99
	T3	77.71	3.20	77.16	3.96	0.48
SND	T1	73.70	2.52	73.73	3.54	0.93
	T2	74.12	2.75	73.92	3.68	0.79
	T3	75.91	2.87	74.96	3.99	0.36
GOGN-MM	T1	73.66	4.49	72.34	4.25	0.18
	T2	77.88	5.31	74.94	3.96	0.02*
	T3	81.99	5.75	76.69	4.06	0.0001*
GOGC-MM	T1	57.05	3.81	55.78	3.93	0.17
	T2	61.86	4.62	58.61	4.13	0.004*
	T3	70.17	5.39	59.75	7.86	0.0001*
GOGN-GOCO	T1	124.37	5.25	126.14	5.01	0.07
	T2	124.45	5.28	126.42	5.87	0.07
	T3	121.73	6.09	125.52	5.62	0.004*
ARTANGLE	T1	143.96	7.62	147.39	6.53	0.04
	T2	143.42	6.79	147.68	7.39	0.01*
	T3	143.70	7.81	147.55	7.20	0.03*
GONANGLE	T1	123.55	6.19	124.77	6.44	0.16
	T2	124.14	6.73	124.61	6.48	0. 56
	T3	119.96	6.79	122.95	6.63	0.04*
SUMANGLE	T1	392.19	3.81	394.92	5.93	0.03*
	T2	392.82	4.57	395.44	6.53	0.06
	T3	388.91	4.19	393.49	6.84	0.002*
GONSLING	T1	52.95	4.61	51.48	3.98	0.17
	T2	51.89	4.51	50.50	4.49	0.19
	T3	49.78	4.55	49.54	4.14	0.77
CORSLING	T1	70.57	3.77	73.29	4.72	0.01*
	T2	72.26	4.35	74.11	4.91	0.07
	T3	70.18	4.69	73.42	5.31	0.01*
RAMH-MM	T1	43.47	3.43	42.62	4.54	0.18
	T2	48.44	4.19	44.73	5.35	0.001*
	T3	56.50	6.11	48.48	5.31	0.0001*
CORL-MM	T1	71.50	4.88	70.65	3.92	0.38
	T2	75.39	4.95	73.30	4.01	0.08
	T3	80.56	6.00	74.41	4.29	0.0001*
CORLCRAN	T1	1.02	0.20	0.99	0.05	0.41
	T2	0.99	0.06	1.01	0.06	0.55
	T3	1.02	0.06	1.01	0.06	0.48

MANDIBLE-TEETH:

MDCROWD	T1	-0.95	3.92	-0.39	5.68	0.75
	T2	-0.55	2.79	-1.66	1.49	0.66 (N 3)
	T3	-1.66	3.78	-3.84	5.34	0.17
SPEE	T1	2.16	1.05	2.16	0.89	0.97
	T2	1.71	0.79	2.56	4.89	0.73
	T3	2.04	0.70	2.25	0.86	0.46
L3-3I	T1	26.53	2.01	26.00	1.50	0.24
	T2	26.42	1.73	25.73	1.64	0.19
	T3	26.08	1.87	25.57	1.88	0.32
L3-3B	T1	30.77	2.08	30.37	1.79	0.42
	T2	31.18	1.56	30.99	3.79	0.09
	T3	30.59	2.33	29.89	1.95	0.21
ARCHL	T1	24.13	2.52	23.13	2.21	0.05*
	T2	22.11	3.20	19.93	2.92	0.001*
	T3	21.04	3.37	19.39	3.49	0.01*
L-IRREG	T1	3.85	3.96	4.43	3.33	0.18
	T2	0.44	0.57	0.42	0.71	0.52
	T3	2.24	1.77	1.39	1.48	0.02*
LITTLE-A	T1	63.06	3.91	59.87	4.12	0.0002*
	T2	60.55	6.08	54.36	6.22	0.0001*
	T3	58.36	6.89	52.97	6.39	0.0003*
I-NB-DEG	T1	26.43	6.69	27.69	6.24	0.43
	T2	27.58	5.36	28.95	4.87	0.36
	T3	25.31	4.91	27.54	4.44	0.04*
I-NB-MM	T1	3.65	2.15	4.05	2.08	0.40
	T2	4.18	1.77	4.40	1.55	0.61
	T3	3.68	1.59	4.26	1.66	0.13
I-APO-MM	T1	-0.28	2.82	0.83	2.82	0.04*
	T2	0.92	2.19	1.51	1.68	0.16
	T3	0.46	2.05	1.09	1.84	0.16
I-APO-DEG	T1	23.13	5.48	24.12	4.99	0.59
	T2	27.66	4.46	27.74	4.85	0.72
	T3	27.46	4.75	27.34	4.64	0.68
IMPA	T1	98.62	6.71	95.70	12.39	0.16
	T2	99.56	6.89	97.92	6.47	0.16
	T3	99.24	7.42	96.92	6.11	0.12
FMIA	T1	61.26	6.30	59.92	7.15	0.29
	T2	59.99	4.84	58.69	6.19	0.32
	T3	61.02	12.63	60.86	5.66	0.27

MANDIBLE-GROWTH DIRECTION:

GOGN-SN	T1	31.63	3.17	34.53	5.47	0.01*
	T2	32.15	4.26	35.19	6.26	0.03*
	T3	28.99	4.16	34.11	6.52	0.0004*
FMA	T1	21.24	3.79	24.19	4.85	0.01*
	T2	21.56	4.26	24.51	5.91	0.04*
	T3	18.03	7.64	23.52	5.94	0.001*
FAC-AXIS	T1	89.78	3.50	88.44	4.39	0.27
	T2	89.38	3.87	87.74	4.70	0.26
	T3	91.26	4.06	88.34	5.42	0.03*
FAC-TAPE	T1	69.99	3.82	67.72	3.98	0.01
	T2	69.07	4.14	67.01	4.18	0.02*
	T3	71.25	4.40	67.93	4.29	0.001*
MAND-ARC	T1	29.98	4.82	29.87	5.87	0.52
	T2	31.07	5.25	30.59	6.38	0.72
	T3	35.19	5.44	33.13	6.09	0.10
FAC-ANGL	T1	88.70	2.42	88.17	3.31	0.40
	T2	89.20	2.73	88.72	3.78	0.52
	T3	90.55	2.95	89.67	3.89	0.41

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differences, $p < 0.05$
S.D. = Standard deviation
N = Sample

(SN-MM: p = 0.0001 and SAR-MM: p = 0.0001), the upper first bimolar width (U6-6I: p = 0.04 and U6-6B: p = 0.04) and the upper first molar position relative to Pterygoid root vertical (UM-PTV-MM: p = 0.05) (Table LI).

The <u>maxillary versus mandibular</u> variables (combination of maxillo-mandibular variables) showing significant differences between males and females, including anteroposterior, vertical and occlusal measurements, were the posterior facial height (POSFACH-MM: p = 0.03), the anterior to posterior facial height ratio (SGO-NME: p = 0.03), the overbite (OBB: p = 0.003) and the total malocclusion severity (TMSCORE: p = 0.0003) at the initial observation (T1); the posterior facial height (POSFACH-MM: p = 0.0001), the anterior to posterior facial height ratio (SGO-NME: p = 0.02) and the total malocclusion severity (TMSCORE: p = 0.001) at the end of treatment (T2); the posterior facial height (POSFACH-MM: p = 0.0001), the anterior facial height (ANTFACH-MM: p = 0.0001), the ratio between the latter two (SGO-NME: p = 0.001) and the occlusal plane angle (OCC-SN: p = 0.0001) at the final observation (T3) (Table LII).

Significant <u>soft tissue</u> differences between females and males included the following variables, being the upper lip to E-plane (U-LIPE-MM: p = 0.03), the anteroposterior dimension of the nose (NOSE-MM: p = 0.02) and the inferior sulcus depth (ISULH-MM: p = 0.03) at the initial

TABLE LI

DIFFERENCS BETWEEN MALE AND FEMALE GROUPS FOR A NUMBER OF MAXILLARY VARIABLES

VARIABLES		MALE		FEMALE		
		MEAN	S.D.	MEAN	S.D.	p
MAXILLA-DIMENSIONS:						
SN-FH	T1	10.39	2.53	10.33	2.52	0.92
	T2	10.59	2.68	10.68	2.58	0.75
	T3	10.19	2.60	10.59	2.72	0.25
SNA	T1	81.68	3.75	81.09	3.46	0.35
	T2	79.46	3.53	79.60	3.52	0.75
	T3	79.84	3.31	80.21	3.68	0.88
ANSPNS-SN	T1	7.05	2.69	7.82	2.99	0.31
	T2	8.55	3.25	7.94	3.21	0.36
	T3	8.05	3.39	7.75	3.13	0.41
A-CONVEX	T1	3.93	2.92	3.83	2.72	0.82
	T2	1.48	2.42	2.23	2.78	0.29
	T3	0.02	2.78	1.82	3.01	0.01*
SADANGLE	T1	124.65	4.84	122.77	4.46	0.10
	T2	125.25	4.91	123.17	4.64	0.05*
	T3	125.24	5.77	122.96	4.58	0.11
SN-MM	T1	72.48	3.44	71.46	3.02	0.15
	T2	75.62	2.92	72.87	3.10	0.001*
	T3	79.17	3.01	74.02	3.46	0.0001*
SAR-MM	T1	36.39	4.08	34.19	2.79	0.02*
	T2	38.29	3.92	35.57	2.77	0.001*
	T3	39.76	3.73	36.13	3.41	0.0001*

MAXILLA-TEETH:

MXCROWD	T1	0.14	5.45	0.56	6.28	0.89
	T2	----				
	T3	-0.73	5.81	-2.29	4.58	0.91
U6-6I	T1	50.95	3.97	48.79	3.19	0.02*
	T2	52.31	3.28	48.92	3.51	0.0001*
	T3	50.49	3.41	48.91	3.14	0.04*
U6-6B	T1	54.77	3.84	52.16	3.03	0.002*
	T2	56.27	3.29	53.05	6.09	0.0001*
	T3	54.00	3.45	52.42	2.83	0.04*
I-NA-DEG	T1	22.19	10.02	23.48	8.56	0.22
	T2	22.42	9.43	22.71	7.88	0.80
	T3	23.36	8.07	21.74	7.10	0.45
I-NA-MM	T1	3.99	2.86	4.23	2.88	0.63
	T2	3.07	2.90	2.69	2.43	0.67
	T3	3.92	2.58	3.23	2.61	0.37
I/-FH-DEG	T1	114.01	9.58	114.65	8.31	0.52
	T2	112.15	8.51	112.79	7.92	0.69
	T3	113.13	6.96	112.37	7.21	0.79
I/-FACAX-DEG	T1	5.34	9.53	3.23	8.06	0.13
	T2	7.01	7.83	4.70	6.87	0.15
	T3	7.05	6.33	5.69	5.93	0.29
I/-APO-MM	T1	7.22	3.11	7.33	3.17	0.79
	T2	4.18	1.94	4.39	1.61	0.57
	T3	4.01	1.69	4.66	2.03	0.06
UM-PTV-MM	T1	16.98	4.06	17.17	3.58	0.79
	T2	20.01	5.58	20.37	4.41	0.77
	T3	24.29	4.87	22.25	4.12	0.05*
UM-CCV-MM	T1	15.93	4.17	15.98	3.46	0.69
	T2	18.74	5.79	18.93	4.39	0.69
	T3	22.91	5.08	20.59	4.17	0.06

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differences, $p < 0.05$
S.D. = Standard deviation

TABLE LII

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS FOR MAXILLO-MANDIBULAR VARIABLES

VARIABLE		MALE		FEMALE		
		MEAN	S.D.	MEAN	S.D.	p
MAXILLA TO MANDIBLE:						
ANB	T1	4.86	2.55	4.28	2.29	0.21
	T2	2.95	2.05	3.12	1.99	0.90
	T3	2.13	2.29	3.05	2.22	0.11
L-FACH	T1	42.99	4.19	43.90	4.59	0.23
	T2	43.57	3.79	45.24	5.29	0.09
	T3	42.90	4.46	44.71	5.23	0.07
POSFACH-MM	T1	75.78	4.75	73.64	4.85	0.03*
	T2	82.29	6.34	76.84	5.31	0.0001*
	T3	91.47	6.90	81.13	5.79	0.0001*
ANTFACH-MM	T1	115.62	6.17	116.09	5.84	0.56
	T2	124.84	8.04	121.33	6.62	0.09
	T3	131.19	7.22	123.69	6.95	0.0001*
SGO-NME	T1	65.59	3.38	63.56	4.77	0.03*
	T2	65.98	3.94	63.62	5.28	0.02*
	T3	69.73	3.84	65.76	5.32	0.001*
WITS-MM	T1	2.11	3.89	0.65	3.88	0.07
	T2	0.89	3.19	0.19	2.96	0.18
	T3	1.07	4.06	0.65	3.39	0.70

OCCLUSION:

OJB	T1	6.67	3.61	5.94	3.09	0.28
	T2	3.02	0.98	2.75	0.75	0.30
	T3	3.19	1.55	3.16	1.02	0.57
OBB	T1	4.84	1.29	3.86	1.47	0.003*
	T2	3.02	1.02	2.70	0.93	0.23
	T3	2.95	1.22	2.72	1.02	0.53
TMSCORE	T1	91.08	5.51	86.49	4.99	0.0003*
	T2	88.99	5.28	84.89	4.51	0.001*
	T3	91.02	5.95	88.85	5.69	0.09
BOLTON A	T1	79.23	2.10	78.15	2.10	0.18
	T2	-----				
	T3	77.74	2.77	77.49	6.51	0.84
BOLTON P	T1	92.35	2.19	91.43	1.90	0.10
	T2	----				
	T3	90.74	2.41	90.35	6.88	0.77
I-I	T1	127.64	12.15	125.66	10.39	0.23
	T2	128.19	9.88	126.36	9.02	0.46
	T3	130.34	8.48	128.80	7.37	0.44
OCC-SN	T1	16.55	3.45	17.10	6.06	0.92
	T2	16.85	3.67	18.13	4.44	0.18
	T3	12.53	3.58	17.00	4.87	0.0001*
MOLAR L	T1					0.28 x
	T2					0.07 x
	T3					0.30 x
MOLAR R	T1					0.09 x
	T2					0.81 x
	T3					0.57 x
CANINE L	T1					0.49 x
	T2					0.12 x
	T3					0.14 x
CANINE R	T1					0.16 x
	T2					0.83 x
	T3					0.19 x
OPENBIT	T1					0.87 x
	T2					0.13 x
	T3					0.54 x
ANTXBIT	T1					0.32 x
	T2					0.43 x
	T3					0.91 x
POSTXBIT	T1					0.55 x
	T2					0.65 x
	T3					0.06 x
ROTATE	T1					0.74 x
	T2					0.26 x
	T3					0.33 x

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differences, $p < 0.05$
x = CHI-SQUARE Test
S.D. = Standard deviation

observation (T1); the upper lip to E-plane (U-LIPE-MM: p = 0.01), the upper lip curl to H-line (SAHLINE: p = 0.02), the upper lip thickness (ULIPTH-MM: p = 0.001), the upper lip taper (ULIPTAP-MM: p = 0.0001), the H-angle (HANGLE: p = 0.01) and the inferior lip sulcus (ISULH-MM: p = 0.001) at the end of treatment (T2); the lower lip to E-plane (L-LIPE-MM: p = 0.001), the anteroposterior dimension of the nose (NOSE-MM: p = 0.01), the upper lip thickness (ULIPTH-MM: p = 0.0001), the upper lip strain (ULIPSTR-MM: p = 0.0001), the lower lip to H-line (LIPH-MM: p = 0.001), the inferior lip sulcus (ISULH-MM: p = 0.0001) and the soft tissue chin thickness (STCHIN-MM: p = 0.01) at the final observation (T3) (Table LIII).

Significant differences existed between the sexes in respect to extraction and nonextraction treatment regimes. Males had less extractions as part of their orthodontic treatment in comparison to females (p = 0.02) (Table LIV). The Little Irregularity Index (Little, 1975) recorded at the final observation (T3) also differed between the sexes ($p < 0.05$) (Table LV).

12.5 Discussion

When orthodontic treatment is completed before or during the period of developmental growth a progressive change in location of the dentition in relation to the rest of the face can be expected. The dentition will become

TABLE LIII

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS FOR SOFT TISSUE VARIABLES

VARIABLES		MALE		FEMALE		
		MEAN	S.D.	MEAN	S.D.	p
U-LIPE-MM	T1	-0.19	2.29	-1.38	2.36	0.03*
	T2	-3.51	1.59	-4.52	2.00	0.01*
	T3	-6.23	2.89	-5.64	1.97	0.07
Z-ANGLE	T1	69.19	6.72	69.76	7.97	0.71
	T2	74.19	4.39	75.17	6.79	0.46
	T3	77.06	15.03	76.72	6.79	0.22
L-LIPE-MM	T1	0.67	2.97	0.39	3.16	0.70
	T2	-1.94	1.99	-2.25	2.16	0.52
	T3	-4.92	2.33	-2.95	2.51	0.001*
STFAC	T1	89.34	2.81	88.94	3.56	0.58
	T2	90.02	2.86	89.52	4.02	0.52
	T3	91.78	2.94	90.49	3.86	0.19
NOSE-MM	T1	12.52	1.65	13.52	2.06	0.02*
	T2	15.93	1.84	15.93	2.28	0.97
	T3	19.01	2.11	17.46	2.32	0.01*
SUPSULD	T1	-10.13	2.93	-9.59	3.02	0.36
	T2	-9.45	2.83	-8.66	2.77	0.18
	T3	-7.92	3.34	-8.47	3.12	0.23
SAHLINE	T1	7.15	2.12	6.50	2.25	0.29
	T2	5.39	1.50	4.48	1.73	0.02*
	T3	4.78	1.82	4.69	1.67	0.92
ULIPTH-MM	T1	14.68	1.42	14.75	1.59	0.94
	T2	16.87	2.14	15.41	1.81	0.001*
	T3	17.99	1.74	15.57	1.87	0.0001*
ULIPTAP-MM	T1	11.54	2.08	11.45	2.19	0.59
	T2	14.61	1.78	12.83	1.81	0.0001*
	T3	15.28	2.13	12.53	2.17	0.0001*
ULIPSTR-MM	T1	3.15	1.57	3.31	2.21	0.37
	T2	2.26	1.77	2.57	1.58	0.37
	T3	2.71	1.93	3.04	2.07	0.44
HANGLE	T1	17.93	3.97	16.40	3.69	0.08
	T2	14.76	3.02	12.89	3.03	0.01*
	T3	12.17	4.08	12.46	3.39	0.52
LIPH-MM	T1	0.81	2.16	1.33	2.19	0.28
	T2	0.39	1.56	0.87	1.39	0.16
	T3	-0.46	1.66	0.83	1.49	0.001*
ISULH-MM	T1	-5.71	2.16	-4.60	2.38	0.03*
	T2	-5.73	1.75	-4.31	1.81	0.001*
	T3	-6.96	2.17	-4.54	1.87	0.0001*

STCHIN-MM	T1	9.87	2.12	10.28	2.12	0.43
	T2	10.47	1.85	10.47	2.18	0.99
	T3	12.28	2.56	10.70	2.16	0.01*

p = Significance level, $p < 0.05$ (WILCOXON 2-Sample Test)
* = Significant differences, $p < 0.05$
S.D. = Standard deviation

TABLE LIV

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS FOR INITIAL ANGLE CLASSIFICATION AND FOR EXTRACTION AND NONEXTRACTION TREATMENT

VARIABLE	p	
ANGLE CLASSIFICATION	0.32	x
EXTRACTION VS NONEXTRACTION	0.02*	x

p = Significance level, $p < 0.05$
* = Significant differences, $p < 0.05$
x = CHI-SQUARE test

TABLE LV

DIFFERENCES BETWEEN MALE AND FEMALE GROUPS: DESCRIPTIVE STATISTICS FOR THE LITTLE IRREGULARITY INDEX (Little, 1975)

MALE:

	T1		T2		T3	
VARIABLE	MEAN	S.D	MEAN	S.D.	MEAN	S.D.
L-IRREG	3.35	3.96	0.44	0.57	2.24*	1.77

FEMALE:

	T1		T2		T3	
VARIABLE	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
L-IRREG	4.43	3.33	0.42	0.71	1.39*	1.48

S.D. = Standard deviation
* = Statistically significant difference, $p < 0.05$ (WILCOXON 2-Sample Test)

progressively less protrusive as was noted in Chapter 7 with the post-orthodontic uprighting of the lower incisor teeth. The ideal location of the dentition for example in a 1?-year-old boy, should be planned with the expectation that in the succeeding months, the developmental growth changes will carry the rest of the facial structures forward relative to the dentition to a greater degree than would be true in a girl of similar age (Baum, 1961).

Orthodontists must consider these changes when planning orthodontic treatment. Visual treatment objectives have already been a tremendous advance in this respect (Johnston, 1975; Ricketts et al., 1979; Jacobson and Sadowsky, 1980; Holdaway, 1984). Earlier studies have also shown that it is imperative to take note of growth and sex differences. It was reported that mandibular growth increments closely followed the statural growth pattern (Ludwick, 1958). The standing height of a subject measured at four-monthly intervals and plotted on a height velocity chart, can be used to give an indication of the maximal pubertal growth spurt. This occurs normally between twelve and sixteen years for boys and between ten and fourteen years for girls (Sullivan, 1983). It is suggested to have appliances in the mouth a year preceeding the maximal growth spurt in order to utilise this accelerated growth in order to attain the clinician's set orthodontic goals. This prediction appeared to be more accutate for boys (95%) than for girls (Sullivan, 1983).

An examination of physical anthropologic work in the field of growth prediction might not be such a far fetched idea as it could provide orthodontists with the additional information to establish more accurately the end of the developmental growth level of an individual. This then, might provide orthodontists with the means to disclose the amount of dentofacial changes to be anticipated in the post-orthodontic phase (Baum, 1961). Various skeletal parameters and their relationship to the frontal sinus have been studied in order to aid the orthodontist in predicting mandibular growth (Rossouw, Lombard and Harris, 1990).

The mature size as well as the percentage of growth completed can be predicted with fair accuracy from a child's present size and from his skeletal age as determined by Todd's method (Bayley, 1943a, 1943b). More recently, studies using the ossification events of the hand-wrist radiograph were used to assess the pubertal growth spurt (Greulich and Pyle, 1976; Hagg and Taranger, 1982; Fishman, 1982, 1987). These authors support this method as the most enlightening in respect of maturity of a subject's developmental status. This method must, however, be supplemented by a clinical examination. Dental age appeared not to be vey accurate in this regard (Suthpen, 1985). It did, however, give a better indication, although still weak, of the pubertal growth spurt in girls (Hagg and Taranger, 1984). The mean pubertal growth spurt was reported to be two years later in boys. An individualized evaluation is the best, as subjects were shown to deviate from this mean by three to six years (Sinclair, 1978).

A secular trend has been noticed in girls the past 300-400 years indicating an increase in size as well as an ealier onset of menarche (Proffit, 1986).

Sexual dimorphism is widely reported, as was previously noted, and various ways were mentioned to determine and distinguish craniofacial patterns between males and females (Broadbent et al., 1975 in Table XLVIII; Riolo et al., 1974, 1979). There was no significant age difference between the sexes in this study (Table XLIX), which made it ideal to assess differences amongst the variables studied.

Krogman (1955) discussed the findings of several authors regarding the level of sexual development in relation to growth expectation. He concluded that, in general, sex maturation signals the end of significant growth increments. Thus, children at a high level of sexual maturity for their age, may be expected to have little growth potential and little prospect of further dentofacial change. It was reported that 99 per cent of adult stature was achieved at 16.4 and 14.6 years in American boys and girls respectively (Nicholson and Hanley, 1953). Recent studies, however, in respect of the continuum of growth in the aging subject showed changes well into adulthood which is supported by the post-pubertal changes experienced in the present study (Behrents, 1984). "Growth" in the post-orthodontic period may be responsible for the dental changes experienced (Behrents, 1984) and also for the changes reported as relapse of treated dentitions (Behrents et al., 1989; Little, 1990). It can, however, also happen that this growth might enhance the excellence of a treated occlusion (Behrents, 1984).

It is naive to expect the bones of the craniofacial skeleton to remain stable after treatment. The practitioner that mentally imparts stability of the dentition to the well-treated subject after treatment is not being realistic. On average, most dentitions fortunately remain reasonably stable following orthodontic treatment, but this is due mainly to the post-treatment growth characteristics of the subject being in favour rather than against the treatment itself. As was noted previously, it seems that those changes which do occur in the dentition during the period following treatment, are growth related. The statement made by Parker (1989) that "retention may be forever", seems to be validated by the findings of the present study. Retention should thus be continued consistent with the amount of growth activity which is occurring and on the basis of continued growth, retention should be continued into the twenties and thirties if possible. Growth is important during treatment and it must also be planned for, used, and respected after treatment (Behrents et al., 1989). No long-term studies have been conducted to show whether any damage to the teeth or periodontium occurs when permanent retention is employed. Should the orthodontist thus feel conservative in this regard, stability can be maintained of well aligned incisors, and perhaps more so for the lower incisors, by interproximal reapproximation (Williams, 1985; Joseph, Rossouw and Basson, 1991).

Mensuration of mandibular variables at the end of treatment (T2) and at the end of the post-orthodntic period (T3) showed the significant differences between the sexes to be mainly growth related (Table L). The mandibular dimensions which changed significantly were the corpus length (GOGN-MM and CORL-MM), posterior mandibular height (GOGC-MM and RAMH-MM), rotation direction of the mandible (ARTANGLE, GONANGLE, SUMANGLE, CORSLING, GOGN-SN, FMA and FAC-AXIS) and the indicator of the chin morphology, facial taper (FAC-TAPE). The mandibular dental measurements which showed significant differences between T2 and T3, were mainly those pertaining to the arch length measurements (ACRHL and LITTLE-A). These are mainly growth related (Moyers, 1988). The only mandibular incisor position variable showing a significant difference was the I-NB-MM. This could be ascribed to the facial pattern differences in males and females. This incisor measurement showed that the males had less protruding dentitions at the end of treatment (T2) (males: mean 4.18 mm and females: mean 4.40 mm) and that the males, possibly as a result of later mandibular growth, showed more post-orthodontic (T3) uprighting of the mandibular incisor measured to the NB-line (males: mean 3.68 mm and females: mean 4.26 mm). The mandibular lower incisor irregularity measurements showed the same correction in alignment with no significant difference between males and females at the end of treatment (T2) (males: mean 0.44 mm and females: mean 0.42 mm). A significant difference, however, was experienced at T3 (males: mean 2.24 mm and females: mean 1.39 mm) (Table L and LV). The difference in growth, as noted, may have contributed to the significant differences measured, but it could also be speculated that males were not as conscientious about wearing their retention appliances especially as later maturity is expected (Greulich and Pyle, 1976; Sullivan, 1983).

The maxillary variables showing significant differences also reflected the difference in morphology between the sexes (Table LI). The convexity at point A (A-CONVEX) was significantly reduced during the post-orthodontic period (T2-T3). Although no significant difference was experienced at the end of treatment (T2) (males: mean 1.48 mm and females: mean 2.23 mm), significant differences were, however, noted post-orthodontically (T3) (males: mean 0.02 mm and females; mean 1.82 mm). This change was in harmony with the larger increment of mandibular growth in the male group ($p < 0.05$). The post-treatment (T2) cranial base length (SN-MM and SAR-MM) measured significantly different between males and females (mean SN-MM 75.62 mm - males and 72.87 mm - females; mean SAR-MM 38.29 mm - males and 35.57 mm - females) and also significantly different at the final observation (T3) (mean SAR-MM 79.17 mm - males and 74.02 mm - females; mean SAR-MM 39.76 mm - males and 36.13 mm - females). This is in accord with the growth changes expected and in harmony with the mandibular growth changes. The male group showed a significant larger bimolar dimension throughout the study (T1-T3). The upper molar mesial movement (UM-PTV-MM) showed that the male group had significantly more mesial first molar movement or migration (males: mean 24.29 mm and females: mean 22.25 mm) which supported the differences in the mandibular arch length as well as the ultimate sign of these changes, the Little Irregularity Index (1975).

The significant difference in the extraction pattern (Table LIV) might play a role in this occurrence. The male group had less extractions as part of the treatment regime (males 38.71% and females 64.81%), which leads to the speculation that the extractions in the female group could have created enough space for ideal positioning of teeth and subsequently less post-orthodontic lower incisor crowding. It was previously reported that subjects who had extractions as part of their treatment experienced less mandibular incisor crowding and were more stable than nonextraction cases (Davies, 1971). Little, Wallen and Riedel (1981) noted, however, that no significant difference existed between extraction and nonextraction groups which is in contrast with the results shown in the present study with the data pooled (Chapter 10). This finding by Little, Wallen and Riedel (1981) reiterates why the data of the present study was pooled and when comparative findings were shown for certain parameters and not for others, it was separated. In this search for excellence in treatment results, the objective was to assess the males and females separately, due the fact that similar differences in the treated samples may also exist as were reported for untreated subjects by Riolo et al. (1974). Psychological hindrances in the female sample relating, for example, to reluctance in headgear wearing as a reason for performing nonextraction treatment, could also have played a part. It must, however, be added that the other factors described as possible aetiologic factors of post-orthodontic crowding, could contribute individually or as a group to lower incisor crowding.

No significant differences could be shown for the measurements normally used to describe the anteroposterior skeletal (ANB and WITS-MM) and dental (according to the Angle (1899, 1907) classification) variables from the initial to the final observation (T1-T3) (Table LII and LIV). The male sample showed significantly larger vertical dimensions (Table LII) from T1 to T3 (POSFACH-MM: mean increase males 75.78 mm to 91.47 mm; females 73.64 mm to 81.13 mm; ANTFACH-MM: mean increase males 115.62 mm to 131.19 mm and females 116.09 mm to 123.69 mm). The males experienced greater anti-clockwise mandibular rotation than the females (SGO-NME at T1: males 65.59% and females 63.56%; at T3: males 69.75% and females 65.76%). This closing rotation of the mandible could influence the lower incisor alignment detrimentally (Björk and Skieller, 1972, 1983) and is borne out by the significant difference in the Little Irregularity Index (1975) as was previously demonstrated (Table L and LV). Only two of the occlusal variables reported in Table LII changed significantly from T2 to T3 (TMSCORE: mean increase males 88.99 to 91.02 and females 84.88 to 88.85; OCC-SN: mean decrease males 16.85 degrees to 12.53 degrees and females 18.13 degrees to 17.00 degrees). The total malocclusion score difference was greatly influenced by the maxillary bimolar width increase which was larger for the males than the females. There was, however, a greater increase in the female group bringing it closer to the male severity score. This resulted in no significant (p = 0.09) difference at the final observation T3.

The occlusal plane angle (OCC-SN) should ideally not be changed during treatment as it was reported to remain stable during growth and would return to the original value if changed (Ricketts et al., 1979). The original OCC-SN measurements (T1) were 16.55 degrees for the males and 17.10 degrees for the females. The measurement for the female group remained reasonably stable from T1 to T3, but the occlusal plane for the male group, although practically unchanged during treatment (T1-T2), changed significantly following treatment (T2-T3). Growth changes in the mandible and the nasomaxillary complex could be responsible for this occurrance in the males and thus also be partly to blame for the larger incisor irregularity score. It appeared that the other occlusal variables showed no significant sexual dimorphism. This could possibly be due to the fact that successful corrections attained amongst these variables either stayed stable or equal changes in both groups were measured.

Soft tissue findings were presented in Table LIII. The upper (U-LIPE-MM) and lower lip (L-LIPE-MM) to the E-line (Ricketts, 1981) showed significant differences at T2 and T3 respectively. The upper lip was significantly more retrusive in the females at the end of treatment (T2) (males: mean -3.51 mm and females: mean -4.52 mm). The lower lip, although not significantly different between the males and the females, was also more retrusive in the females (males: mean -1.94 mm and females: mean -2.25 mm). The lower lip (LIPH-MM) to H-line (Holdaway, 1983) showed similar significant differences at the final observation (T3). This could be ascribed to the larger percentage of extractions performed as part of the treatment regime in the female group resulting in more retrusive dentitions at this evaluation. The males, however, surpassed the female values and showed significantly more retrusive lower lip (L-LIPE-MM) measurements at the final observation (T3) (males: mean -4.92 mm and females: mean -2.95 mm). This is supported by the difference in the H-angle (HANGLE) measurement which showed a significant difference at the end of treatment (T2) between the sexes. Although the upper lip (U-LIPE-MM) also showed more retrusive values, it was not significantly different between the two groups (males: mean -6.23 mm and females: mean -5.64 mm). This could be attributed to nose (NOSE-MM) and soft tissue chin (STCHIN-MM) enlargement producing lips that appear relatively retrusive. Caution must be expressed when evaluating the lip values. Males showing later, larger and longer growth (Baum, 1961) will become dentally more retrusive as was shown earlier with regard to the lower incisor position. There was a significant difference measured at the end of the post-orthodontic period (T3) for these variables with males showing the larger dimensions (NOSE-MM: males mean 19.01 mm and females mean 17.46 mm; STCHIN-MM: males mean 12.28 mm and females mean 10.70 mm).

Significant differences were measured for upperlip thickness (ULIPTH-MM) and upperlip taper (ULIPTAP-MM) at T2 and T3. The male group recorded larger dimensions. Changes in parameters which may have contributed to the larger inferior lip sulcus measured between T2 to T3, were the combination of a larger soft tissue chin and more retrusive, but proclined lower incisors. Support for these findings were the measurements for lower incisor position to NB line, to APo line and to the mandibular plane (IMPA). The lower incisor incisal edge to NB ($p < 0.05$), APo line ($p > 0.05$) and the IMPA ($p > 0.05$) indicated that the lower incisors were slightly more proclined at the end and following treatment (mean IMPA: males 99.24 degrees at T2 and 99.56 degrees at T3; females 96.92 degrees at T2 and 97.92 degrees at T3). Lower incisor torque control or upright incisor position on basal bone (Tweed, 1954, 1966) are parameters that must be considered during treatment. The more proclined lower incisor teeth of the males remained proclined, but this position does not make it immune from the influence of the mandibular forward growth. This could be a contributing factor, with the others already noted, to more lower incisor crowding in the male group.

There have been numerous reports in the literature on the relationships between general body growth and development, facial growth and development, and a measure of predictability concerning the fate of the dentition after treatment. The dentition of an immature subject must be placed in an "immature" location, that is, more forward than in a mature face. Placing an immature patient's dentition in an adult relationship can only result in a further retrusion of the dentition as the inevitable facial maturation changes take place. For most of our patients orthodontic treatment is commonly finished during the very years when these differences in dentofacial behaviour operate. A distinction must be made in dentofacial relationships and possibly in upper incisor to lower incisor relations between boys and girls during these years. Failure to do so may lead to the unpleasant experience of watching helplessly while the face of a male subject becomes more and more concave as his lips retreat and his nose and chin achieve their adult proportions (Baum, 1961).

From the foregoing findings and discussion, a generalization might be permitted: The dentition of a pre-pubertal girl should be placed further back in relation to the various cephalometric planes than that of a boy in a similar age group. Similarly, a pre-pubertal boy can accept a fuller dentition than a girl of the same age, since the girl probably will experience little or no change in distance from the central incisor plane to the nose and chin point while the boy can expect a significant increase in these distances after the age of thirteen years (Baum, 1961).

12.6 Conclusions

1. Significant mandibular and maxillary dimensional differences were apparent between males and females.

2. The males grew larger, longer and later than the females.

3. Anti-clockwise mandibular rotation was more obvious in males.

4. More extractions were done in the female sample.

5. More lower incisor irregularity was experienced with the male sample.

6. Extractions could influence the stability of lower incisor alignment.

7. The male group who had less extractions as part of their orthodontic treatment attained more retrusive lips with age in comparison to the female group who had more extractions performed during their treatment.

8. Growth, which the orthodontist has no control over, appeared to influence the lower incisor irregularity in the post-orthodontic period.

9. Retention, although equally important for both sexes should be more stringently prescribed and utilised in males.

CHAPTER 13

GENERAL SUMMARY AND CONCLUSIONS

13.1 Introduction

The various components and dimensions contributing to the composition of the craniofacial region have been separately described, discussed and certain conclusions were made (Chapters 4-12). These elements, forming the core of the thesis, were the nasomaxillary complex, the mandible, the anteroposterior dimension of the maxilla versus the same dimension of the mandible, the occlusion, the anterior border of the dentition, the vertical dimension, extraction versus nonextraction treatment, soft tissue changes and sexual dimorphism. In this concluding chapter an attempt is made to summarize the significant findings from which a few broad conclusions emerged. No data in regard to the abovementioned regions are available for this or a comparable South African Caucasian sample. The results are also presented in a format which has not previously been recorded.

The volume of data presented in this thesis contributes generously to the literature and will hold benefits not only for the clinician, but also for the academician who must continuously seek better and more significant ways and means of conducting research of this nature. The thesis is a milestone in this regard and as no such data exists for a comparable sample and it's contribution to research locally and internationally is important. Comparisons with data from other studies are essential, and only by doing so can certain trends for long-term changes in respect to orthodontic treatment be established, confirmed or supported. In this way new data is contributed to the orthodontic literature. All these criteria were satisfactorily met in the present thesis.

This study has direct relevance in respect of the stability and relapse of an orthodontically treated subject. Orthodontists have a concept that they are totally responsible, borne out by post-orthodontic care and treatment, for lasting perfection and stability. However, orthodontists have little control over the biological aspects of growth and development and should not in every case have feelings of guilt when their perfect results show signs of relapse in the long-term (Behrents, 1984).

Enlargement, as a result of growth, creates a constant series of localized imbalances. In most instances growth results in periods of transient balance and ultimately in a state of total equilibrium. The latter state is rarely achieved in a lifetime of biological flux. Facial biologists should appreciate that orthodontic relapse, in most instances, is a normal reaction of the growth process itself (Enlow, 1986). Stability will, certainly, be undermined when one or more of the delicate physiological relationships are overwhelmed by improper diagnosis, the use of inappropriate appliances and/or improper orthodontic technique. Overexpansion of arch width, incomplete correction of anteroposterior relationships and rotations, poor uprighting of lower incisors and incorrect vertical control are but a few examples of factors which could result in relapse. Continued growth of the craniofacial complex after the removal of appliances (Behrents, 1984) could influence the post-orthodontic occlusion as was probably the case in the present study. Because growth of the craniofacial skeleton can not be switched on and off according to the wishes of clinicians, it is naive to assume that the craniofacial morphology is ever stable. A thorough understanding of the principles of craniofacial growth is imperative. If sophisticated therapy is used only to correct malocclusions, and stability is automatically assumed, ultimate failure is guaranteed (Behrents, 1984).

It is important, when assessing relapse, to segregate the changes which result from the orthodontic treatment from those which would have taken place if no orthodontic treatment was instituted (Brown and Duagaard-Jensen, 1951; Lundström, 1969; LaVelle and Foster, 1969; Hunter and Smith, 1972; Sinclair and Little, 1983). Riedel (1975) discussed nine popular causes of relapse, supported by relevant research, and Moyers (1988) added another. They were:

i) Teeth that have been orthodontically moved, tend to return to their former positions. This is especially true for rotations in the incisor regions. In the posterior teeth intercuspation aids retention to some extent.

ii) Elimination of the aetiology of malocclusion will assist in the preventing of recurrence.

iii) Malocclusion should be overcorrected as a safety precaution.

iv) Proper occlusion is a potent factor in holding teeth in their corrected positions.

v) Bone and adjacent tissues must be allowed time to reorganize around newly positioned teeth. If occlusal disharmony still exists post-treatment, it makes little difference as to what kind of retainer is worn or for how long. In such instances when the retainers are removed stability will return at the expense of the dental correction.

vi) If the lower incisors are placed upright over basal bone they are more likely to remain in good alignment.

vii) Corrections carried out during periods of growth are less likely to relapse.

viii) The further the teeth have been moved, the less is the likelihood of relapse to the original position.

ix) Arch form, particularly in the mandibular arch, cannot be altered permanently by appliance therapy. Arch form changes occurring in response to alterations in the muscular environment may be more stable.

x) Many treated malocclusions require permanent retenion devices.

The mean findings of the present study supported the abovementioned statements and also showed that the cephalometric and clinical norms described in the literature are still excellent guidelines in treatment planning. Practically all the variables in the study were treated to these norms and the relapses that occurred were minimal and clinically acceptable. The contribution of the present study in this regard cannot be overemphasized.

Malocclusions are in a stable condition before treatment. The practitioner must endeavour to attain the same situation following treatment. It has, however, been pointed out in the present study that even with an almost zero lower incisor irregularity and more than 90% stability of the molar and canine relationships, changes still occurred within clinically acceptable limits. Proper goals of treatment, excellent appliance control, precise occlusal equilibration and well-chosen retention procedures all contribute to achieving occlusal stability (Moyers, 1988).

The ideal duration of retention has not yet been determined (Reitan, 1967). No satisfactory comparisons have been made between similar malocclusion groups which were similarly treated, but which had greatly different retention times (Joondeph and Riedel, 1985). The literature suggests anything from no retention whatsoever (Englert, 1960; Williams, 1985) to permanent retention (Little, Wallen, Riedel, 1981; Moyers, 1988; Parker, 1989). It is advisable to have some form of mandibular retention until evidence of completion of growth is forthcoming. Retention in the present study was implemented mainly by lower intercuspid fixed retention and the use of maxillary Hawley retaining appliances. Four prefinishers were used as retention appliances and two subjects had no retention device fitted at all. The retention of the maxillary arch was ceased before the mandibular arch. The latter was retained until at least the third molars had shown signs of erupting or were removed as a result of impaction. Retention was implemented for a mean 2 years following treatment (post-retention interval 5 years; post-orthodontic interval 7 years).

Statistically significant and clinically significant are not always the same. The term statistically significant means that an observed difference is unlikely to be merely the effect of chance, not necessarily that the difference is clinically important. Many variables such as radiographic technique, the pencil thickness on a cephalometric tracing, the difficulty of locating a cephalometric landmark or the attrition of a plaster cast may have influenced the data. Hence, all the chapters included significant as well as non-significant data.

The findings of the present study may provide insight in establishing a sense of perspective regarding the level of responsibility that may be accepted by an orthodontist when relapse, rebound or physiologic settling do occur. Moreover, informed consent is a topic of general discussion not only in orthodontic journals, but also at meetings of orthodontic societies. The results of the present study will provide tremendous assistance to the orthodontist in this regard.

13.2 Discussion

From the early days of orthodontics to the present time, orthodontists have been faced with the primary problem of moving each dental unit to its proper position in the dental arch. The secondary problem, though often subjugated to an inferior role, has been to maintain these teeth in their new positions with retaining devices (Straub, 1949). Retainers succeed in some mouths, but fail in others. This finding encouraged many orthodontists to examine their treatment modalities, as they suspected that the incorrect placement of the teeth was responsible for relapse rather than the failure of different types of retainers and retention methods used (Straub, 1949). Tweed (1944), Strang (1943, 1954) and Nance (1947) realised that a full complement of teeth could not be placed in their correct positions in all cases of crowding without "ballooning" out the dental arches, and without changing the apical base sizes. In such instances relapse often occurred either while the retainers were being worn or after their removal, and it is doubtful whether any retention device could maintain them (Straub, 1949).

Nance (1947) convincingly showed that the stability of the dentition was dependent upon the correct positioning of the teeth over skeletal (basal) bone. He added that the correction of any and all malocclusions was not the result of stimulating bone growth, but depended rather upon an accurate appraisal of the amount of bone available in which to move the teeth into their proper arch relationships and good occlusion. It is conceivable that there exists an envelope in which tooth movement may be accomplished without significant relapse and that extreme changes violating these limits are more likely associated with long-term relapse. This envelope has been described by the clinical and cephalometric norms widely published in the literature.

The only way to ensure continued satisfactory post-treatment alignment is probably by the use of permanent fixed or removable retention (Little, Riedel and Artun, 1988; Parker, 1989). The number of hours during which the removable retention appliances are worn is, however, out of the control of the orthodontist.

The purpose of the present longitudinal study was not to study the effects of prolonged retention, but to assess and describe changes which occur in occlusions following orthodontic treatment.

The craniofacial complex is made-up of very intricate hard and soft tissue structures. Changes occurring in even the smallest of these structures could contribute to relapse of an ideally treated occlusion. The different parts of this "puzzle" must thus, either by normal growth or perhaps orthodontic treatment, be placed in their correct positions. Moreover, patients undergoing orthodontic treatment should be informed beforehand of the possibility of post-treatment change. They must understand the limitations of orthodontics and their own roles in the maintenance of the treated results. Orthodontists should assume that stability will not follow treatment, and in so doing can plan against, and prevent undesirable post-treatment changes (Little, Riedel and Artun, 1988).

13.2.1 Changes in the maxilla, mandible and supporting structures

A knowledge of basic anatomy (Longmore and McRae, 1985; DuBrul, 1988) and how normal growth influences it (Enlow, 1968), is important in orthodontics. In this study growth changes were cited according to norms reported in the literature (Riolo et al., 1974; Moyers et al., 1976; Ricketts, 1981). It was deemed important to take cognizance of these norms as pre-treatment, treatment and post-treatment growth played its part in the present study.

A variety of treatment modalities are able to influence the dimensions of the craniofacial skeleton (Ricketts et al., 1979; Proffit, 1986; Moyers, 1988).

In the present sample the mean position of point A was changed to a more retrusive position during treatment. This could have been due to a variety of reasons including, for example, upper incisor retraction, upper incisor palatal root torque and extraoral traction to the maxilla. This posterior movement of point A was reflected by the mean SNA and A-CONVEX measuements (Chapter 4, Table VIII). The mandible on the other hand did not significantly change its spatial anteroposterior position during treatment (Chapter 5, Table XVI). Treatment mechanics were meticulously excecuted in respect of the palatal plane position and mandibular clockwise (opening) rotation. The palatal plane was kept unchanged and the mandible was not significantly rotated open (Table VIII and XVI).

Normal increases as expected, were observed in the overall mean maxillary and mandibular dimensions. The Björk/Jarabak facial rotation pattern determination (Jarabak and Fizzell, 1972) indicated a counterclockwise pattern for the pooled sample of the present study. The cranial base angle remained unchanged throughout the study (Table VIII and XVI). The post-treatment forward growth displacement and closing rotation of the mandible in combination with the more retrusive stable maxillary position correlated significantly, but weakly with the post-treatment lower incisor irregularity (Table IX and XVII). Caution should thus be excercised when planning to distalize the maxilla. The retruded position of the maxilla may restrict the late forward growth of the mandible and the subsequent uprighting of the lower incisor teeth as a result of this movemant is a possible aetiologic factor of lower incisor crowding. Reports supporting these findings have been published by Björk and Skieller, 1972, 1983; Richardson, 1986 and Behrents <u>et al</u>., 1989.

13.2.2 Anteroposterior maxillary versus mandibular relationship

The anteroposterior dimensions of the maxilla and mandible are frequently used to classify and to determine the severity of a skeletal disharmony between the two jawbones (Steiner, 1953; Jacobson, 1975; Ricketts, 1981). Occlusal relationships in the anteroposterior reference plane have also served as a popular method of classifying malocclusions (Angle, 1899, 1907). Many authors disagree with the Angle classification system, but its usefulness has outlasted most critics (Ackerman and Proffit, 1969; Mangazini, 1974). Concepts of the ideal occlusion have been described including the molar relationship in various planes (Andrews, 1972, 1976). Irrespective of the shortcomings of the Angle classification system, it correlated very favourably with the ANB classification when the number of subjects in each classification was assessed (Table 0 and I). Both of these anteroposterior classifications produced similar information in regard to the "relative" severity of the malocclusions, however at closer scrutiny it was shown that discrepancies do exist and that an Angle malocclusion is not necessarily analogous with its skeletal counterpart (Table 0).

The mean ANB angle significantly decreased throughout the period of observation, but true to the reports in the literature, the mean Wits appraisal (Jacobson, 1975) did not follow the ANB decrease and remained stable. It appears that most of the ANB reduction during treatment was the result of relative posterior movement of point A rather than mandibular forward growth. The mandible showed forward growth only during the post-treatment period and contributed to the ANB reduction during this period (Table XIX). Similar findings were reported by Holdaway (1956). No significant correlation could be shown between these variables and post-treatment mandibular incisor irregularity (Table XXI).

13.2.3 Occlusal changes

The establishment of occlusal relationships were described by Baume (1950) and Friel (1954). Ideal occlusion, although rarely achieved in nature (Proffit, 1986), has been described in the literature by various authors (Ricketts, 1969; Ricketts et al., 1979; Andrews, 1972, 1976; Roth, 1981).

Normal dimensionsal changes have been shown during this present study to serve as guidelines when planning orthodontic treatment. It was shown that dimensions such as mean mandibular intercanine width (Table XX) remained stable during normal growth and a dimension such as the mean arch length decreased with age (Table XXV). These and other norms were described by Moyers et al. (1976) in Chapter 7 of this thesis. Similar changes were measured during the orthodontic treatment period (T1-T2) of this study (Table XXVIII). As noted above, similar findings have also been recorded in other studies.

post-orthodontically while the upper incisor showed a slight mean mesial movement as a consequence of these maxillary and mandibular changes (Table XXVIII).

The mean overjet values, although reduced to acceptable norms (Moyers et al., 1976; Ricketts et al., 1979; Moyers, 1988) tended to return to their original mean values, but this was not a statistically significant change (Table XXVIII). The mean overbite remained stable after orthodontic correction (Table XXVIII), possibly as a result of the ideal mean interincisal relationships which were obtained. Schudy (1963) reported similar findings in respect of the interincisal angle and overbite. Mean openbite values showed signs of returning to the original malocclusion state possibly due to the presence of uneliminated aetiological factors during the immediate post-treatment period. No overt habits were, however, noted at the final observation (T3) of the present study. Crossbites seemed to remain reasonably stable once corrected (Table XXX). The mean measurements for rotations showed that an increase in the frequency extent of rotations post-treatment, was possibly in part due to the mean increase of the post-treatment lower incisor irregularity as well as rebound of previously rotated teeth (Table XXX). The reappearance of rotations seems to be a universal problem. Even with the use of surgical fiberotomies, corrected rotations still show small percentages of relapses. This procedure does appear, however, to be beneficial (Edwards, 1970; Boese, 1980). It is a recommended policy to overcorrect rotations as this variable showed signs of increasing post-treatment (Table XXX).

Although the mean occlusal plane angle was not significantly changed during treatment, it was slightly enlarged, possibly as result of the Class II mechanics during treatment (Tweed, 1966). This parameter appeared to become more acute relative to the anterior cranial base (Sella-Nasion plane) during the post-orthodontic period of this study (Table XXVIII). This post-orthodontic change was, however, in a direction back towards the original mean value of the recorded parameter, it actually reduced to a mean value smaller than the pre-treatment one and it can be referred to as part of the rebound effect of orthodontic treatment or relapse. The mean mandibular occlusal curve or Curve of Spee (Von Spee, 1890) tended to return to its pre-treatment value following orthodontic treatment (Table XXX). Orthodontists should thus strive towards a post-treatment flat Curve of Spee (overtreatment) to accommodate for this change. Space will be created when this phenomenon occurs and possibly lead to less lower incisor crowding (Sandusky, 1983).

The mean Bolton tooth-size discrepancy for the sample was within the norm (Table XXIX). The mean anterior measurement, however, did appear slightly larger than the norm described by Bolton (1958, 1962) and it is suggested that even this small increase in the mandibular anterior tooth mesio-distal dimensions could influence the lower incisor post-treatment crowding.

Third molars, irrespective whether they were removed before the final observation (T3) or were congenitally absent, were only noted as being present or not present in the mouth. It was then only recorded as a yes or no and no metrical measurements were recorded. Third molars were absent in 80.7% of the jaws (quadrants) studied (Table XXXI). It may be speculated that the relatively small mean post-orthodontic increase (within clinical norms) in lower incisor irregularity can partly be ascribed to the absence of the wisdom teeth. The study did, however, not include a sufficiently sensitive assessment method to support this speculation.

A total malocclusion score was developed to give an indication of the severity of malocclusions (Sadowsky and Sakols, 1982). The mean total severity score, similar to the abovementioned, did not significantly change during the study which indicates a tendency for the post-treatment occlusion to return to the original situation. The mean differences measured during treatment included treatment changes. The mean post-treatment changes echoed changes due to the accompanying growth (Table XXVIII). A large number of the post-orthodontic changes in the present study appeared to be growth-related.

Lower incisor irregularity is an acceptable clinical indicator of post-treatment relapse (Little, 1975). Only the mesial movement of the upper molar correlated significantly, but weakly, with this parameter. The molar movement which normally occurs as part of the mesial migration of the dentition forms part of the post-orthodontic growth variables. All the other occlusal variables showed no correlation with the post-orthodontic Little Irregularity Index (Table XXXII). The post-treatment and post-orthodontic Little Irregularity Index of the present study were lower than for other studies (Little et al., 1988).

13.2.4 Vertical changes

The vertical dimensions of orthodontic subjects can be assessed by means of cephalograms. The mandibular plane angle is normally used in this respect (Downs, 1948; Steiner, 1953; Tweed, 1954). Ricketts (1981) besides using the Frankfurt mandibular plane angle to assess the vertical relationship of the mandible, also suggests the use of the facial axis angle, facial angle and lower facial height to record the vertical dimension or mandibular growth direction. The Björk/Jarabak analysis (Jarabak and Fizzell, 1972), as used in the present study, emphasized the mandibular rotation patterns of the subjects. The mean changes of these parameters appeared to be towards a closing rotation of the mandible (Table XXXVIII). Vertical dental problems normally follow the skeletal pattern, but a vertical skeletal problem does not necessarily accompany a vertical dental problem (Graber and Swain, 1985).

Overbite stability is often used to determine vertical stability. Overbite correction and stability have been reported with great controversy (Fogel and Magill, 1970). Various ways of correcting this dimension have been described in the literature (Schudy, 1963; Ricketts et al., 1979). Schudy suggested molar extrusion while Ricketts et al. advocated incisor intrusion to correct overbite. The interincisal angle also plays an important part in overbite stability (Schudy, 1963). The mean overbite correction in the present study remained stable (Table XXXVIII) possibly due to vertical control during treatment and to the achievement of interincisal goals as described by Schudy (1963). Extraction therapy and the counterclockwise rotation of the mandible did not seem to influence the overbite stability negatively.

Although no significant correlations were shown between the vertical variables and the post-orthodontic lower incisor irregularity (Table XXXIX), various measurements changed significantly in the post-treatment period (Table XXXVIII). The vertical dimension was maintained rather than increased during the active orthodontic treatment. This probably contributed in keeping the mean post-orthodontic lower incisor irregularity to a minimum. Tweed (1966) noted that when the mandibular plane angle is increased during treatment, it always tends to return to its pre-treatment value. If this change, as well as the normal closing rotation tendency of the mandible (Björk and Skieller, 1972, 1983; Riolo et al., 1974, 1979), are taken into consideration then the importance of these contributing factors to lower incisor crowding is realised. The counterclockwise rotation of the mandible causes the lower incisors to become more upright with a subsequent decrease in dental arch space for these teeth, resulting in lower incisor crowding (Table XXXVIII). Similar findings were reported in the literature (Richardson, 1986; Perera, 1987).

13.2.5 Extraction versus nonextraction treatment

Extraction of teeth in the treatment of malocclusions is one of the oldest and most controversial subjects in orthodontics (Cole, 1948). It is much easier to extract teeth than to establish the absolute necessity to follow this philosophy (Delabbarre, 1815).

Successfully treated malocclusions can be achieved with either extraction or nonextraction therapy. The frequency of extractions vary greatly among orthodontists. Peck and Peck (1979) reported an average prevalence of 42.1%, while others found a range between 5% and 87% (Weintraub et al., 1989). The present study was divided into 56% extraction, and 44% nonextraction cases (Table I).

It has been shown that extractions per se do not necessarily produced stable results, but that meticulous diagnosis and planning of orthodontic treatment possibly could contribute in this regard (Nance, 1947).

All the significant differences between the extraction and nonextraction groups were set out in Chapter 10. The general picture of this evaluation showed no significant differences between the extraction and nonextraction groups at the post-treatment stage (T2) and post-orthodontic (T3) stage for the lower incisor irregularity of the pooled male and female groups (Table XLIV). This suggested that irrespective of treatment regime post-treatment crowding of mandibular incisors occurred in a sample where no distinction is made between males and females. It must, however, be mentioned that the post-orthodontic lower incisor irregularity was within clinically accepted limits (Little, 1975). Other studies reported similar findings (Shields, Little and Chapko, 1985; McReynolds and Little, 1991).

13.2.6 Soft tissue changes

One of the first orthodontists to write about facial harmony and the importance of the facial soft tissues was Angle (1907). An important goal for orthodontic treatment is to improve the facial harmony by correcting disproportions (Rakosi, 1982; Holdaway, 1984; Proffit, 1986; Bishara, Hession and Peterson, 1985).

It was reported that young subjects have fuller lips as compared to the more retrusive lips found in adults (Foster, 1973; Ricketts, 1981). Males have more retrusive lips than their female counterparts when assessed according to the E- and H-lines. Female profiles are also described as being straighter than are mature male profiles (Mauchamp and Sassouni, 1973). Similar mean findings were recorded in the present study (Table XLVI). These findings are in accordance with normal soft tissue growth changes (Table XLV). The lips became significantly more retrusive throughout the duration of the present study possibly due to a combination of treatment procedures and normal growth processes. This finding was borne out by a reduction in the overjet (Table XXXIV), a lower incisor position which was not significantly retruded (Table XXXIV), and a significant increase in nose prominence, soft tissue chin thickness and a larger soft tissue facial angle (Table XLVI).

Significant, but weak correlations of the lower incisor irregularity were shown for both the Merrifield Z-angle (Merrifield, 1966) and Holdaway soft tissue facial angle (Holdaway, 1983) (Table XLVII). No other significant correlations were shown for the soft tissue variables.

13.2.7 <u>Sexual dimorphism</u>

Differences between craniofacial parameters in males and females have been widely published (Hellman, 1932; Baird, 1952; Barnes, 1954; Horowitz and Thompson, 1964; Lewin and Hedegard, 1970; Broadbent <u>et al</u>., 1975; Greulich and Pyle, 1976; Forsberg, 1979; Behrents, 1984). Boys attain their pubescent growth about two years later than do girls (Krogman, 1955). The absence of any significant age differences, at the various time intervals studied, between the male and female groups of the present study made for ideal correlation of variables (Table XLIX).

The facial dimensions of males were reported to be larger than those of females (Forsberg, 1979). It was also reported that males grew later, longer and larger (Baum, 1961). Similar findings were noted in the present study and significant differences between the sexes were reported in Chapter 12.

Mandibular and maxillary mean differences in the present study were mostly growth-related. The males showed greater counterclockwise rotation. Males appeared to be dentally more retrusive than females. This obviously also influenced the soft tissue profile as was previously noted. Moreover, males showed more mean upper first molar mesial migration, although they had less extractions as part of the orthodontic treatment than did females.

The female group who had more extractions as part of their treatment regimes, also showed a significantly smaller value of the post-orthodontic lower incisor irregularity (Table LII). This significant finding is in contrast to the results of the pooled male and female sample of the present study and also contradicts the results of other studies with such pooled data (Shields, Little and Chapko, 1985; McReynolds and Little, 1991). According to the Little Irregularity Index (Little, 1975), it appears as if the extractions could have benefitted the stability of the treated dentitions. It must, however, be remembered that other variables such as motivation during treatment and retainer wear, which was subjectively assessed, could have played a part in the result.

13.3 Conclusions

1. Ideal treatment goals are essential if acceptable stability of orthodontic treatment is to be achieved.
2. Sound orthodontic technique could help to attain these goals.
3. Distalization of point A, creates the possibility of a more retrusive anteroposterior maxillary post-treatment position. This may contribute to lower incisor crowding in the post-orthodontic period.
4. Growth of the mandible occurred in keeping with the norms quoted in the literature.
5. Orthodontic treatment complimented facial growth. No adverse effects such as mechanical opening of the bite, which could lead to relapse of treated dentitions, took place.
6. A forwards and closing rotation of the mandibular growth arc occurred monotonically throughout the present study. The continual forward growth of the mandible, which was accentuated by the distalization of point A, could have

added to the mean post-treatment crowding of the mandibular incisors. Anti-clockwise (opening rotation) mandibular rotation was more obvious in males.

7. The mean anteroposterior dimensions SNA, ANB and A-CONVEX decreased throughout the study. This occurred mainly because of treatment (T1-T2), but was growth related during the post-orthodontic period.

8. The mean overjet, although significantly corrected during treatment, showed a mean post-orthodontic increase.

9. Significant, but weak correlations were shown between the anteroposterior maxillary and mandibular positions and the post-orthodontic Little Irregularity Index.

10. The mean post-pubertal growth changes which were measured in the mandible, contributed to the continued decrease in the point A-point B dimension, and although no significant correlations were shown between the post-orthodontic lower incisor irregularity and the variables ANB, A-CONVEX and WITS-MM, it may possibly have a contributing influence on the late lower incisor crowding.

11. Molar and canine relationships once established in Class I, remained extremely stable and no significant relationship could be shown between these and the late lower incisor crowding.

12. Similar numbers of subjects were grouped according to Class I, II or III when the skeletal classification according to angle ANB and the dental classification according to the Angle molar classification was used. However, discrepancies existed between the two

classification systems which resulted in some subjects being grouped in one class when using the angle ANB and grouped in another class when using the molar relationship.

13. Expansion of the mandibular arch beyond the original intercanine dimension is likely to lead to failure, as this dimension tends to decrease below the original measurement in the long-term.

14. The mean anteroposterior measurement of the arch length significantly decreased throughout the study. Although related to treatment during the initial phase, growth and occlusal forces were mainly responsible for the post-treatment changes.

15. Change in arch length appears to be a major cause of mandibular incisor irregularity.

16. Normal interincisal angular relationships contribute to post-orthodontic overbite stability. Overbite remained stable in this study in contrast to other studies which reported relapses in this dimension.

17. The ideal cephalometric norms for incisor position should be adhered to, as once attained, they tend to remain stable within clinical norms.

18. No strong, significant correlations could be shown between lower incisor crowding and the various other dental variables measured in this study.

19. A post-treatment occlusion with a flat curve of Spee and with all rotations eliminated could contribute to stability of the orthodontically treated dentition.

20. Correct diagnosis tc distinguish between extraction and nonextraction treatment of malocclusions, is imperative.

21. The extraction of teeth does not necessarily assure long-term stability of the lower incisors.

22. More extractions were carried out in the female sample which showed a smaller value for the Little Irregularity Index.

23. Greater lower incisor irregularity was recorded for the male sample, in whom a larger number of nonextraction treatments were performed. The male soft tissue profile showed, irrespective of the type of treatment, less protrusive lips in comparison to the female sample.

24. From the conclusions 22 and 23, it appears that extractions could influence the stability of the lower incisor alignment.

25. The differences experienced between extraction and nonextraction groups were mainly found in the maxillary and mandibular dimensions.

26. No strong, significant correlations could be shown between the relationship of the general soft tissue changes and the post-orthodontic lower incisor irregularity.

27. The male group attained more retrusive lips with age than did the female group.

28. Growth appeared to be responsible for most of the post-treatment changes.

29. Significant differences were shown between the dentofacial dimensions of males and females.

30. The lower incisor irregularity increases following orthodontic treatment could be attributed mainly to growth changes. The prerequisite when making this assumption is that clinically acceptable norms should be the order of the day at the end of active treatment.

31. Orthodontists have little control over post-orthodontic growth changes and cannot be held responsible for natural changes which might influence an ideally treated dentition.

32. Patients and parents should be informed that changes brought about mainly by growth, will take place during the post-orthodontic period and could influence the alignment of teeth detrimentally.

33. Retention, although equally important for both sexes, should be more stringently prescribed and utilised in males as they showed more post-orthodontic lower incisor irregularity.

ORTHODONTISTS SHOULD BE AWARE THAT THE PERFECT RESULT HAS NOT BEEN, AND PERHAPS WILL NEVER BE, OBTAINED. THERE WILL FORTUNATELY ALWAYS BE MORE TO LEARN WHICH COULD BRING THE CLINICIAN CLOSER TO PERFECTION.

THE END

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