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Begg orthodontic therapy in retrospect

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raymond levin

begg orthodontic therapy in retrospect

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I

It is unrealistic to assume that, in contrast to all other systems of the human organism which change throughout life, the occlusion is static after orthodontic treatment.

II

The final examination after (orthodontic) treatment should be as extensive as the initial examination.

III

Prolonged retention after orthodontic treatment is of limited value.

IV

Stability of changes effected in the dentition during treatment can be assessed at an early stage of the postretention period, while, changes in the periodontium due to treatment can only be evaluated at a much later stage.

V

There is no scientific basis for equating the principle of the arch as used in architecture to a comparable application in orthodontics, to promote the stability of the dental arches.

VI

Compartmentalisation of dental training produces a fragmentary approach to general dental care.

VII

There is as yet no justification for mandibular third molar germectomy to prevent mandibular incisor crowding.

VIII

Methods to prevent dental caries and periodontal disease should be introduced to children of preschool age and their parents.

IX

The forces which are used and co-ordinated in reaching the moon are much, much simpler than the forces and co-ordination of forces which are at work in craniofacial morphogenesis.

(A. G. M. van Melsen: *The morphogenesis of the human head. Acta Morphol. Neerl-Scand* 10:3-8, 1972).

X

The current trend to more conservative attire is a precursor of a similar political trend.

rijksuniversiteit te groningen

begg orthodontic therapy in retrospect

**proefschrift ter verkrijging van het doctoraat
in de geneeskunde aan de rijksuniversiteit te groningen
op gezag van de rector magnificus dr. a. wattel
in het openbaar te verdedigen op
woensdag 15 januari 1975 des namiddags te 4.00 uur**

door raymond israel levin

geboren te johannesburg

**from the department of orthodontics, state university of groningen,
netherlands, (head: prof. dr. h.s. duterloo)**

state university groningen

begg orthodontic therapy in retrospect

**a dissertation to fulfil the requirements for
the degree of doctor of medicine at the university of groningen
on authority of the rector magnificus dr. a. wattel
and to be defended in public on
wednesday the 15th of january 1975 at 4.00 p.m.**

by raymond israel levin

born in johannesburg

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to my parents

preface

In general, the aim in treating malocclusions and oro-facial dysplasias is to obtain a biologically optimal functional balance of the oro-facial structures: teeth, bone and soft tissues. In addition to providing a basis for the longevity of the dentition, the facial skeleton and integumental structures are also more favourably maintained over a longer period and facial aesthetics are improved.

The mechanics of orthodontic treatment are of considerable intricacy. In addition, patients are usually growing and it is the individual oro-facial growth pattern which adds to the intricacy of the therapy. Moreover, the treatment period is lengthy and the continued cooperation of the patient is required.

Treatment results can only be effectively evaluated some time after the end of treatment as further changes may occur in the posttreatment period. An evaluation of results, besides indicating the success or failure of treatment also serves as a feedback to facilitate the formulation of treatment objectives and procedures. To this end an investigation was undertaken of certain treatment and posttreatment changes in patients treated using the Begg orthodontic technique.

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introduction

1.1 Development of the Begg orthodontic theory and technique

The background to the development of the Begg orthodontic theory and technique is to be found partly in the study made by Begg (1954), of the dentition and skulls of precolonial Australian Aborigines.

In this study Begg found in relation to age, a progressive interproximal as well as occlusal attrition. He suggested that this attrition plays a major role in the maintenance of optimal function of the dentition. He proposed that the lack of attrition in the dentition of civilized man is a major cause of malocclusion. This concept offers, according to Begg, the rationale for extraction of teeth in the treatment of malocclusion.

Begg also introduced the concept of "differential force" (Begg 1956, 1961, 1965). This concept explains how, during treatment, intra-oral anchorage occurs. He explained differential force, as a force which, when used between two groups of different teeth, can cause different types of tooth movement of the two groups. Swain (1969), however, proposed the term "differential resistance" as he states that, although equal and opposite forces are exerted, it is the tissue resistance to different types of tooth movement that creates the different responses of the two groups of teeth.

In addition to the two concepts mentioned above, Begg (1954), introduced a new treatment technique based on these concepts. This technique differed from the then current fixed appliance techniques in the use of a specially developed 0.018 inch diameter stainless steel arch wire. Inverted ribbon arch brackets (Angle, 1916) were used as buccal attachments on anterior teeth.

Principles of the technique which is now used, were presented by Begg (1956). Extensive descriptions of theory, appliances and treatment procedures are to be found in the text books by Begg and Kesling (1971). In this text book the

records illustrating the treatment of a wide range of malocclusions are shown. A chapter written by Williams is devoted to the analysis of lateral cephalometric radiographs. He describes in general terms some of the changes which occur during and following treatment. However, the changes which have occurred during the treatment, and specifically thereafter, have not been extensively analysed.

There is general disagreement as to the manner in which certain changes take place during Begg treatment. Longterm results have not been widely studied and there are few unanimous opinions regarding the causes of the stability of treatment results or of posttreatment changes. A number of studies have recently appeared on different aspects of Begg therapy and other relevant phenomena. These studies will be referred to in subsequent chapters.

1.2 Objectives

The purpose of the investigation described in this thesis is to study in retrospect a number of changes of the dentition, its occlusion and the facial skeleton which occurred during and following treatment in a sample of thirty patients treated with the Begg fixed appliance technique. A further understanding of these changes may contribute to the formulation of treatment objectives, the use of the fixed appliance and the selection of retention appliances.

The following changes during the treatment and posttreatment periods are studied: overbite, overjet, incisor positions, mandibular and maxillary crowding and intercanine widths. Using the structural method of superimposing mandibles (Björk 1963, 1969), the direction of condylar growth, mandibular rotation, and occlusal plane rotation are investigated. Aspects of anterior facial profile changes are examined. Further, the interrelationship of a number of the variables studied are investigated. Additionally, an evaluation of the status of the dentition and the periodontal tissues is made.

Due to the nature of the investigation the sequence of chapters is arbitrary. However the changes in variables described in one chapter may be related to both changes in variables described in previous as well as subsequent chapters.

material and methods

2.1 Material

Orthodontic treatment using the Begg fixed appliance technique was first undertaken in the Orthodontic department of the State University of Groningen in 1960. Since 1960, the technique has been used for increasingly larger numbers of patients in this department. For the present investigation, 30 patients were selected. All were treated by staff members of the department under the supervision of C.Booy. The selection was based mainly on the suitability of records and on the criteria mentioned below.

2.1.1. Treatment technique

The technique used in the present investigation, was as described by Begg (1961, 1965). The theory, the appliances and treatment procedures were first described by Begg in 1954 and 1956. An extensive description of the theory, the appliances and treatment procedures is to be found in the text book by Begg and Kesling (1971).

Retention procedures were usually as follows: within a few days of the removal of the fixed appliances, removable retainers were provided for retention of the maxillary and mandibular dental arches. For the first three months the patients were advised to wear the retainers day and night. For the next three months retainers were worn at night only and thereafter less frequently. After approximately nine months all retention procedures were stopped.

2.1.2. Selection Criteria

The following criteria were used in the selection of patients:

- a. an age at the start of treatment of 10 to 15 years;
- b. malocclusions were excluded from the investigation which were classified as

Class III, Class II division 2 or openbite;

- c. all permanent teeth (erupted or unerupted) had been present at the start of treatment (third molars excepted);
- d. the four first premolars had been extracted at the start of treatment;
- e. the treatment with the fixed appliance had been satisfactorily completed. This was evaluated by inspection of the dental casts, taken at the time of removal of the fixed appliance.
- f. the postretention period was from 12 to 36 months.

2.1.3. Sample

The group of 30 patients meeting the selection criteria showed the following general characteristics. At the start of treatment the average age was 12.8 years (SD 1.2.). The youngest patient was 10 years 8 months and the oldest was 15 years 2 months. There were 12 females and 18 males.

The average period for which fixed appliances were worn was 27.8 months (S.D. 6.9). The shortest period was 16 months and the longest 44 months. The retention period was approximately nine months and the postretention period was at least 12 months. The average posttreatment period was 32 months (S.D. 6). The shortest posttreatment period was 21 months and the longest was 44 months. The malocclusions of the patients were classified according to the Angle system by inspection of the dental casts. Seven malocclusions were classified as Class I malocclusions, six as borderline cases (Class I and Class II characteristics), and 17 as Class II division 1 malocclusions.

2.1.4. Records

Complete records had to be available. They consisted of dental casts, lateral cephalometric radiographs, intraoral radiographs and colour slides, and black and white profile photographs. The sets recorded the status of the patient at:

- a. The start of treatment (examination 1 or the initial examination);
- b. The removal of the fixed appliance (examination 2 or the end of treatment);
- c. The treatment results at least one year after the retention procedures had ended (examination 3 or the final examination).

2.1.5. Presentation of data

The treatment period refers to the period between examination 1 and 2. The changes which took place were calculated by subtracting the values found at examination 1 from 2 (2-1). The posttreatment period refers to the interval between examination 2 and 3. The changes were calculated by subtracting the values found at examination 2 from 3 (3-2). The total period of the examination refers to the

interval between examination 1 and 3. The changes (net changes) were calculated by subtracting the values found at examination 1 from 3 (3-1).

2.2 Measuring on dental casts

2.2.1. Determination of reference points

The three sets of dental casts from each patient were placed side by side. The points to be registered on the first dental cast were determined by inspection, and marked with a soft graphite pencil. When attrition of the cusps of the canines had occurred the second and third casts were compared with the first cast in order to determine the position of the cusps.

2.2.2. Reference points

For each set of dental casts 28 reference points were determined (Figure 2.1.). A numerical code was used to denote the points of the upper and lower cast. The upper cast was denoted 01, the lower 02. The points were numbered one to fourteen and were defined as follows:

points two and thirteen: the cusps of the canines;

points one, three to twelve and fourteen: the points denoting the greatest mesio-distal widths of the canines and incisors.

2.2.3. Measuring with the Optocom

The Optocom (Van der Linden et al., 1972) is described as a monocular microscope with a reticle in the lens, mounted above a two dimensionally movable table. The position of the table is electronically recorded on paper tape.

The upper dental cast was mounted on a base which could be inclined. The base was then adjusted to orientate the dental cast, so that the occlusal plane was horizontal. The occlusal plane was defined as the plane through the mesiobuccal cusps of the first molars and the midpoint of the incisal edge of the right central incisor. The lower dental cast, mounted on a base, was placed in occlusion on the upper dental cast using an instrument called the orientation tower. The orientation tower has two parallel platforms with precision pins corresponding to holes in the bases on which the dental casts were mounted. Once the bases had been positioned in the orientation tower and the dental casts were in occlusion they were removed from the tower and the points recorded. The coordinates were registered to 0.1 mm.

The casts were measured separately. The base was placed on the two-dimensionally movable table of the Optocom in a fixed position using precision pins and holes. The point to be registered was moved under the reticle of the microscope

Figure 2.1. Reference points on the six anterior maxillary and mandibular teeth.

using the movable table. The position of the point was then recorded. For a series of points, a predetermined sequence of registration was used. A computer programme was written to convert the coordinates registered, to the actual dimensions.

2.2.4. Error of measurement

The error of measurement was determined by using a double determination procedure. From ten patients, two sets of impressions were taken on the same day and two sets of dental casts were made. The two series of dental casts thus obtained were prepared for measurement. The coordinates of the 14 points were registered and the actual measurements derived. Thus two series of measurements were obtained. The mean differences between the two series of measurements, standard deviations, standard errors and method errors were calculated (Table 2.1.). If the mean difference is greater than twice the standard error, the mean difference between two series of measurements is significant and indicates a systematic discrepancy between the two series of measurements. The differences between the series of measurements were found to be not significant. The largest method error was that of the maxillary anterior dental arch circumference, 0.44 mm.

Table 2.1. Error of measurement of the dental arch measurements on the dental casts.

Variable	Mean difference	S.D.	S.E.	Sign	M.E.	n
Maxillary ICW	0.00 mm	0.02	0.00	NS	0.16	10
Maxillary Circum	−0.04 mm	0.05	0.02	NS	0.44	10
Mandibular ICW	−0.01 mm	0.02	0.01	NS	0.15	10
Mandibular Circum	−0.01 mm	0.03	0.01	NS	0.21	10

Definitions of the variables are given in Chapter 7.2.

2.3 Measuring on lateral cephalometric radiographs

2.3.1. Cephalostat

Standardised lateral cephalometric radiographs were taken with the cephalostat of the department of orthodontics. The focus-film distance used was 375 cm. For the first and second examinations the object-film distance was 12 cm. For technical reasons the object-film distance was changed to 20 cm prior to the final examination.

The central x-ray beam was perpendicular to the film and passed through the central axis of both ear-rods. The patient was placed in the cephalostat with the midsagittal plane of the head parallel to the film. The right side of the head was towards the film. Furthermore, the head was positioned so that the Frankfort horizontal plane was parallel to the upper and lower border of the film.

The difference in object-film distance has no significant influence on the comparison of angular measurements in the midsagittal plane (Beek and van der Linden 1958). Angular measurements of projections of objects not in the midsagittal plane are influenced by changes in the object-film distance. This is, however, compensated by the large focus-film distance which was used and the use of the midpoint in identification of bilateral structures. The alteration in object-film distance results in a difference in enlargement of the final radiographs of 2.3 percent. To compare linear measurements made with the new and old radiographic techniques, the linear measurements made using the new radiographs were all reduced by 2.3 percent.

Figure 2.2. Dental and skeletal reference points and reference structures in the mandible on the lateral cephalometric radiographs.

2.3.2. Determination of reference points

Tracings of all radiographs were made using matt acetate Kodatrace and a sharp 5H pencil. All reference points selected were identified according to their definitions and marked. Bilateral reference points were both identified and the mid-point between them used for registration. For point sella (S), a special procedure was used. Point sella was defined as the midpoint of the hypophyseal fossa. It was identified by placing the outline of sella turcica over millimeter paper to determine the midpoint of the hypophyseal fossa.

2.3.3. Reference points

The following reference points were determined. The reference points are illustrated in Figures 2.2 and 2.3.

Figure 2.3. Soft tissue reference points on the lateral cephalometric radiographs.

Skeletal reference points

- A** Subspinale. The most posterior point on the anterior contour of the maxilla between the anterior nasal spine and prosthion (Downs 1948).
- ANS** Anterior Nasal Spine. The apex of the anterior nasal spine.
- Ar** Articulare. The intersection of the radiographic images of the external contour of the cranial base and the posterior contour of the mandibular condylar head or neck (Björk 1947).
- B** Supramentale. The most posterior point on the anterior contour of the mandibular symphysis (Downs 1948).
- Id** Infradentale. The most antero-superior point on the alveolar margin of the mandible.
- Me** Menton. The most inferior point of the symphyseal outline of the mandible.
- N** Nasion. The most anterior point of the fronto-nasal suture or the deepest point on the contour of the naso-frontal bones if the suture is indistinct.
- Pg** Pogonion. The most anterior point on the contour of the chin determined by a tangent to the chin from nasion.

- PNS Posterior Nasal Spine. The most posterior point of the hard palate in the sagittal plane.
- Pr Prosthion. The most antero-inferior point on the alveolar margin of the maxilla.
- S Sella. The mid point of the hypophyseal fossa.
- M* Point on the tangent to the lower border of the mandible.
- R* Point on the tangent to the posterior border of the ramus.

Dental reference points

- D* Distobuccal cusp of the mandibular first molar.
- Li Incision inferius. The incisal tip of the most anterior mandibular incisor.
- Is Incision superius. The incisal tip of the most anterior maxillary incisor.
- lia Apex of the most anterior mandibular incisor.
- lsa Apex of the most anterior maxillary incisor.

In addition to the reference points the following mandibular reference structures were identified and traced:

- 1 the outline of the mandibular canal;
- 2 the anterior contour of the chin;
- 3 the outline of the inner cortical structure of the inferior border of the mandibular symphysis.

Soft tissue profile reference points

- a The deepest point on the contour between the nose and upper lip.
- b The deepest point on the contour between the lower lip and chin.
- li The most anterior point on the lower lip.
- Is The most anterior point on the upper lip.
- n The most anterior point on the nose.
- na The deepest point on the contour between nose and forehead.
- pg The most anterior point on the chin.

2.3.4. Reference lines and planes**

The following reference lines and planes were used (Figure 2.4).

* The letters used to denote these points were chosen for convenience

** The term plane is commonly used in orthodontic literature to describe a line when examining lateral cephalometric radiographs.

Figure 2.4. Reference lines and planes on the lateral cephalometric radiographs.

- AP AP line. The line drawn from subspinale to pogonion.
- NPg Facial Plane. The line drawn from nasion to pogonion.
- ILi Mandibular incisal line. The line drawn through the points defining the incisal edge and apex of the most anterior mandibular incisor.
- ILs Maxillary incisal line. The line drawn through the points defining the incisal edge and apex of the most anterior maxillary incisor.
- MP Mandibular plane. The line drawn through menton, tangent to the lower border of the mandible.
- OP Occlusal plane. The line drawn through the points defining the incisal edge of the most anterior mandibular incisor and the distobuccal cusp of the mandibular first molar.
- PP Palatal plane. The line through the points defining the anterior nasal spine and posterior nasal spine.
- RP Ramal plane. The line through articulare, tangent to the posterior border of the mandible.
- SN Sella Nasion plane. The line through the points sella and nasion.

Table 2.2. Error of measurement of the dental and skeletal measurements on the lateral cephalometric radiographs.

Variable	Mean difference	S.D.	S.E.	Sign	M.E.	n
overbite	-0.10 mm	0.85	0.26	NS	0.54	10
overjet	0.11 mm	0.55	0.17	NS	0.37	10
Ii-MP	-0.07 mm	0.70	0.22	NS	0.46	10
Is-PP	-0.14 mm	0.81	0.27	NS	0.60	10
Ii-AP	-0.13 mm	0.64	0.20	NS	0.41	10
Ii-Id	0.23 mm	0.66	0.21	NS	0.59	10
Is-Pr	0.10 mm	0.74	0.24	NS	0.48	10
S.N.A.	-0.43°	1.13	0.36	NS	0.83	10
S.N.B.	-0.10°	0.98	0.31	NS	0.66	10
A.N.B.	-0.25°	0.58	0.18	NS	0.42	10
S.N.Pg	0.00°	0.96	0.30	NS	0.63	10
ILi.MP	-1.05°	1.88	0.60	NS	1.47	10
ILs.SN	-0.30°	2.70	0.85	NS	1.83	10
ILs.ILi	0.42°	3.80	1.20	NS	2.45	10
S.N.Pr	0.07°	0.81	0.26	NS	0.60	10
S.N.Id	0.08°	0.99	0.31	NS	0.71	10

Definitions of the variables are given in the respective chapters.

2.3.5. Method of measurement

The x and y coordinates of the predetermined points were registered in a predetermined sequence using a D-MAC Pencil Follower type P.F. 10.000. The instrument is comprised of a "reading table" and an "electronic table".

The tracing to be registered was placed on the reading table and the position fixed using Sellotape. A sight which magnifies 10x and contains a reticle was placed on the tracing and moved across, until the point to be registered lay directly under it. The position was then electronically recorded on paper tape. The coordinates were thereafter transferred to punch cards.

A computer programme was written to convert the coordinates registered to the actual dimensions.

2.3.6. Error of measurement

The double determination procedure was used to evaluate the systematic errors of the cephalometric measurements. Lateral cephalometric radiographs were taken on two separate occasions with an interval of a week, of ten subjects aged 14 or 15 years. The two groups of radiographs were traced, the landmarks were identified and the coordinates registered. Two groups of measurements were made and the mean differences between the two groups, the standard deviations, standard errors, as well as the method errors, were calculated. Thus the sum of the systematic errors in the radiographic technique, the method of tracing and the determination of the coordinates of the reference points could be estimated. If the mean difference is greater than twice the standard error of the difference, a systematic discrepancy between the two groups may exist. The findings are given in Table 2.2. and Table 2.3. No differences in the dental or skeletal measurements were found to be significant (Table 2.2.). In a number of instances, the mean differences were found to be greater than twice the standard error of the mean difference for measurements of the soft tissue profile (Table 2.3.). The method error was found to be largest for measurements relating to the sagittal inclination of the incisors (Table 2.3.). A comparison was made with the method errors of a number of variables from earlier studies (Table 2.4.). Although the measuring techniques and composition of the material used was different, the results of the present investigation are in agreement with those of earlier studies.

2.3.7. Structural method of superimposing mandibles

For superimposing the tracings of the mandibles use was made of the natural reference structures in the mandible as advocated by Björk (1969). These natural reference structures are the fundus of a developing tooth germ, the mandibular canal, the anterior contour of the chin and the inner contour of the cortical plate of the inferior part of the mandibular symphysis. In the present investigation, although, in many patients the fundus of the third molar was visible it was not used as a reference structure due to the possible influence that the extraction of the first premolars may have on the position of the third molars. Furthermore, the age of the sample is such that in most cases at the final examination the third molars were erupting, which makes this reference structure unreliable.

In nine of the 30 cases the outline of the mandibular canal could not be satisfactorily identified and in these cases no mandibular superimposition was attempted.

The three tracings of each patient were superimposed using the reference structures in the mandible and the relative positions were fixed using Sellotape. To define the positions of the tracings relative to each other, pinholes were pierced through all three tracings simultaneously at a position below the symphysis and

Table 2.3. Error of measurement of the soft tissue profile measurements.

variable	Mean difference	S.D.	S.E.	Sign	M.E.	n
na.no.pg	−0.33°	1.61	0.51	NS	1.11	10
na.a.pg	−1.58°	2.76	0.87	NS	1.00	10
a.na.b	0.09°	1.16	0.37	NS	0.78	10
PgN.no	0.43°	1.55	0.49	NS	1.08	10
PgN.a	0.32°	1.26	0.40	NS	0.87	10
PgN.ls	0.60°	0.85	0.27	Sign	0.70	10
PgN.li	0.51°	1.51	0.48	NS	1.08	10
PgN.b	0.20°	0.68	0.22	NS	1.08	10
PgN.pg	−0.18°	0.38	0.12	NS	0.78	10
a – NPg	0.27 mm	1.24	0.39	NS	0.83	10
ls – NPg	0.79 mm	1.22	0.38	Sign	0.97	10
li – NPg	0.56 mm	1.88	0.59	NS	1.30	10
b – NPg	0.27 mm	0.95	0.30	NS	0.65	10
pg – NPg	−0.41 mm	0.54	0.17	Sign	0.43	10

Definitions of the variables used in the investigation are given in Chapter 10.2.

Table 2.4. Comparison of method errors.

Variable	Present Study	Björk (1947)	Solow (1966)
S.N.A.	0.83°		0.63°
S.N.B.	0.66°		0.52°
A.N.B.	0.42°		0.41°
S.N.Pg	0.63°	0.68°	0.62°
S.N.Pr	0.60°	0.62°	
S.N.Id	0.71°	0.60°	
ILs.ILi	2.45°	1.39°	2.68°
ILs.SN	1.83°		1.78°
ILi.ML	1.47°		1.52°
overjet	0.37 mm	0.33 mm	0.24 mm
overbite	0.54 mm	0.36 mm	0.31 mm

Table 2.5. Error of measurements of the structural method of superimposition.

Variable	Mean difference	S.D.	S.E.	Sign	M.E	n
Ar3-1.MP1	-1.83°	15.49	4.90	NS	7.68	10
OP3.RP1	-0.37°	1.47	0.47	NS	0.75	10
MP3.RP1	-1.29°	2.65	0.84	NS	1.20	10
mandibular rotation	1.24°	3.44	1.09	NS	1.60	10

Definitions of the variables are given in the respective chapters.

angle of the mandibles. The Sellotape was removed and the position of the mandibles could again be determined by superimposing the pin holes.

The coordinates of the landmarks and of the pinholes were individually recorded for each tracing. A computer programme was written which could reorientate the coordinates of the pierced points to their previous relationship by superimposing one group of points and then rotating the other three points so that their coordinates again coincided. Using the coordinates of the pinholes as reference the coordinates of the landmarks could be redefined. The original positions of the coordinates of the tracings relative to each other was thus reestablished and the measurements required were calculated.

2.3.8. Error of measurement of the structural method of superimposition

The radiographs of the first and final examination were traced on two separate occasions at an interval of a week. Using the structural method of superimposition, the tracings which were traced on the same day were superimposed, and the measurements were made. As the tracings were of the same radiographs the sum of the error of tracing and superimposing the tracings was estimated. The estimation includes any error which may result from the difference in magnification of the radiographs. The results are shown in Table 2.5.

In no instance was the mean difference found to be significant between two groups of measurements. The method error was found to be large and may be due to the nature of the measuring technique.

2.4 Statistical procedures

The calculation of the measurements and all statistical procedures were performed on the C.D.C. Computer of the Computing Center, State University, Groningen (Head: Dr. D.W. Smith).

For each variable the mean (M), standard deviation (S.D.), standard error (S.E.) and range were calculated. In addition, for double determinations, the method error* (M.E.) was calculated.

The significance of mean changes during the observation period (matched pairs) and the mean difference between two groups (independent samples) was tested using the appropriate Students t-test. For matched pairs the degrees of freedom used in determining the significance of t was n-1 and for independent samples n-2. The product moment correlation coefficient (r) was used to investigate the relationship between two variables. To determine the significance, n-2 degrees of freedom were used. Further, the significance of t and r were determined using two tailed tests. A value of t or r equal to, or less than a probability value (P) of 0.05 was considered to be significant. This indicates, that the probability of the value of t or r being due to chance would arise once in 20 times or less. Significance levels of $P \leq 0.05$ and $P \leq 0.01$ are given for each table.

Advice on statistical procedures was given by L. Th. van der Weele.

Statistical procedures were prepared by L. Th. van der Weele et al. (1974) and the computer programmes were written by D.M. van der Sluis.

*

$$M.E. = \sqrt{\frac{\sum_{i=1}^n d_i^2}{2n}}$$

$d_i = x_i^{(1)} - x_i^{(2)}$, n = number of double determinations.
 $x_i^{(1)}$ is first determination and $x_i^{(2)}$ is second determination
of measurements of individual with index i.

chapter 3

overbite

3.1. Introduction

There are as many methods of treating a deep overbite as there are orthodontic treatment techniques. For each technique there are opposing opinions as to how, and when the treatment should take place. In addition, views differ widely on how the treatment result is attained.

The complexity of the problem of overbite was recognized by Moorrees et al. (1969), who state, "that overbite is a symptom determined not only by the position and inclination of the incisors but by an agglomeration of factors involving disproportionate relationships between the heights of the alveolar processes in the incisor and posterior segments of one or both jaws and even disproportions of vertical facial development". Further, it is frequently observed that the treatment of overbite may be unstable and numerous factors have been investigated to determine the causes of overbite relapse.

In this chapter the changes in overbite will be examined. In subsequent chapters various factors will be examined which may be related to changes in overbite during or following treatment.

3.2. Measurement

Details of the cephalometric procedures and the landmarks and plane used are described in Chapter 2.3. The method of measurement is illustrated in Figure 3.1.

OB Overbite, was defined as the distance from the incisal edge of the most anterior mandibular incisor (Ii) to the incisal edge of the most anterior maxillary incisor (Is), measured parallel to the facial plane (NPg).

Figure 3.1. The method used to determine the overbite (OB), the distance (Is-PP) of the most anterior maxillary incisal edge (Is) to the palatal plane (PP) and the distance (Ii-MP) of the most anterior mandibular incisal edge (Ii) to the mandibular plane (MP).

Table 3.1. Mean values and distribution of individual values of overbite.
Significance level: $n=30$, $t \geq 2.756$, $P < 0.01$.

Variable	n	Mean	S.D.	Range		t	Sign
overbite 1	30	3.48 mm	1.78	0.5	7.1	6.200	$P < 0.01$
overbite 2-1	30	-1.89 mm	1.67	-5.5	1.6		
overbite 2	30	1.58 mm	0.84	0.2	3.6	5.645	$P < 0.01$
overbite 3-2	30	1.42 mm	1.37	-1.3	4.6		
overbite 3	30	3.00 mm	1.57	0.3	6.7	1.749	NS
overbite 3-1	30	-0.47 mm	1.48	-4.8	1.6		

3.3. Results

3.3.1. Mean values and distribution of individual values

The mean values and distribution of individual values are shown in Table 3.1.

At the initial examination, the mean overbite for the sample was 3.48 mm with a standard deviation of 1.78 mm and a range of 0.5 mm to 7.1 mm. During treatment a significant mean reduction in overbite of 1.89 mm with a standard

Table 3.2. Mean values, standard deviations and ranges of the two groups of overbite. Group OBI consists of the ten cases with the largest overbite at the initial examination. Group OBs consists of the ten cases with the smallest overbites at the initial examination.
Significance level: $n=20$, $t>2.101$, $P<0.05$; $t>2.878$, $P<0.01$.

Variable	Group OBI largest overbites, n=10				Group OBs smallest overbites, n=10				tSign	
	Mean	S.D.	Range		Mean	S.D.	Range			
overbite 1	5.43 mm	0.84	4.8	7.1	1.48 mm	0.85	0.5	2.6	10.171	P<0.01
overbite 2-1	−3.43 mm	1.14	−5.5	−1.8	−0.32 mm	1.20	−1.7	1.1	5.773	P<0.01
overbite 2	2.00 mm	0.85	0.7	3.6	1.16 mm	0.77	0.2	2.6	2.315	P<0.05
overbite 3-2	2.28 mm	1.36	0.9	3.5	0.90 mm	1.11	−0.9	2.7	2.490	P<0.05
overbite 3	4.28 mm	1.45	2.2	6.6	2.06 mm	1.07	0.7	3.8	3.894	P<0.01
overbite 3-1	−1.15 mm	1.55	−4.8	0.5	0.58 mm	0.79	−0.8	1.6	2.950	P<0.01

deviation of 1.67 mm occurred. The largest decrease was 5.5 mm and the largest increase was 1.6 mm.

At the end of treatment, the mean was 1.58 mm, with a standard deviation of 0.84 mm and a range of 0.2 mm to 3.6 mm. In the posttreatment period a significant mean increase of 1.42 mm occurred. The standard deviation was 1.37 mm, and the range of individual values was from -1.3 mm to 4.6 mm.

At the final examination the mean overbite was 3.00 mm with a standard deviation of 1.57 mm. The range was 0.3 mm to 6.7 mm. The mean difference between the first and third examination was not found to be significant. The distribution of individual values, however, show considerable individual variation as the standard deviation was 1.48 mm and the range was -4.8 mm to 1.6 mm.

To compare the treatment of small and large overbites the sample was subdivided on the basis of the overbite at the initial examination. Two separate groups containing the ten largest overbites (Group OBI) and the ten smallest overbite (Group OBs) were formed. Table 3.2 shows their mean values, standard deviations and ranges. The significance of mean differences between the two groups were evaluated using the t-test. The changes are illustrated in Figure 3.2.

At the initial examination, Group OBI had a mean overbite of 5.43 mm and Group OBs of 1.48 mm. The mean difference between the two groups was found to be significant. In the treatment period the mean overbite was reduced 3.34 mm in Group OBI, the largest decrease was 5.5 mm and the smallest 1.8 mm. In Group OBs, the mean decrease was 0.32 mm and the range extended from a decrease of

1.7 mm to an increase of 1.1 mm. The mean difference between the two groups was significant.

At the end of treatment, although the mean difference between the two groups was small it was still found to be significant. The mean overbite in Group OBI was 2.00 mm, and the range extended from 0.7 to 3.6 mm while in Group OBs, the mean overbite was 1.16 mm and the range was from 0.2 mm to 2.6 mm.

In the posttreatment period the mean difference between the two groups remained significant. In Group OBI a mean increase in overbite of 2.28 mm was found and of 1.11 mm in Group OBs. The ranges found in the posttreatment period indicate that in Group OBI the overbite increased in all cases. The range was from 0.9 to 3.5 mm. In Group OBs however, the values ranged from a decrease in overbite of 0.9 mm to an increase of 2.7 mm.

At the third examination the mean difference was again found to be significant. In Group OBI, the mean was 4.28 mm and the range 2.2 to 6.6 mm. In Group OBs, the mean was 2.06 and the range 0.7 to 3.8 mm. The mean difference between the net changes was also found to be significant. In Group OBI, the mean was -1.15, and the range from a decrease of 4.8 mm to an increase of 0.5 mm. In Group OBs, the mean was 0.58 mm, the largest decrease was 0.8 mm and the largest increase was 1.6 mm.

It thus appears that the mean overbite remained significantly larger in Group OBI despite the effects of treatment. The line diagram (Figure 3.2) illustrates the individual changes. In Group OBI, there are several cases in which the overbite has been shown to be considerably smaller at the third examination than at the first, and there is only one case in which the overbite was larger at the final examination. In group OBs, there were a number of cases in which overbite had become larger by the final examination.

3.3.2. Correlations

The correlation coefficients are listed in Table 3.3. To measure the relationship between overbite at the first and third examination the correlation coefficient was calculated. It was found to be significant. When considered with the mean values and their standard deviations it appears that there is a tendency for the individual initial overbite to be similar to the overbite at the final examination.

The correlation coefficient between treatment and posttreatment changes was calculated and found to be significant. The correlation coefficient, in combination with the means and standard deviations, indicates that generally a decrease of overbite during treatment is associated with a posttreatment increase of overbite. Such posttreatment changes are slightly less than the treatment changes. It appears that usually some amount of relapse may be expected to occur.

Figure 3.2. Changes in overbite found in Group OBI (large overbites) and Group OBs (small initial overbites).

Table 3.3. Correlation coefficients relating aspects of the overbite examination.
Significance level: $n=30$, $r>0.363$, $P<0.05$, $r>0.464$, $P<0.01$.

Variable	Variable	n	r	Sign
overbite 1	overbite 3	30	0.613	$P<0.01$
overbite 2—1	overbite 3—2	30	-0.539	$P<0.01$
	overbite 3	30	-0.405	$P<0.05$

The relationship of the treatment changes and the overbite at the final examination was calculated and the correlation was found to be significant. The value of the correlation coefficient indicates, that although, there is some relationship between

these two measures it is of a low magnitude and apparently other factors besides the extent of treatment change, are relevant to the depth of the overbite following treatment.

The possible influence of the amount of time elapsed between the second and third examination in relation to the overbite changes was also evaluated. This correlation coefficient between the posttreatment interval and the posttreatment overbite change was not found to be significant ($r=0.048$, $P>0.05$).

3.4. Discussion

The findings indicate that in general, overbite although successfully reduced during the treatment period usually increased in the posttreatment period. There was a significant relationship between the treatment and posttreatment changes which, when evaluated with the mean values and the standard deviations, indicates a tendency for a large or respectively a small overbite decrease during treatment to be associated with a large or respectively a small overbite increase in the posttreatment period. In addition, the significant relationship found between the initial and final overbite confirms that these measures are associated and, when considered with the mean values and their standard deviations, indicates that the initial and final overbites are quite similar.

It must, however, be emphasized that the findings of the individual changes in overbite, also, indicate that there was considerable variation of the changes in the posttreatment period. In some cases with large initial overbite (Group OBI), increases of overbite in the posttreatment period were small, resulting in a successful treatment of the overbite. However, in several other cases a large posttreatment increase was found. In Group OBs, posttreatment increases were generally small, but, the overbite tended to be larger at the final examination than at the initial examination. The comparison of the two groups shows that overbite was relatively more successfully treated in Group OBI, as the decrease in overbite between the initial and final examination was significantly larger in this group.

If all findings are considered, it may be concluded that cases with the largest initial overbite maintained the greatest amount of overbite correction. Furthermore, a large overbite may be reduced during treatment but this correction is not always maintained after treatment.

The finding that the correlation coefficient between treatment changes and the final overbite is significant, although relatively low, indicates that, even if a further reduction of overbite were to occur in the treatment period it would be of little influence on the final results. Moreover, it appears that the magnitude of overbite correction is in itself a factor of limited importance in determining the eventual

Table 3.4. Values of overbite found in the present investigation and in the investigations of Magill (1960), Ludwig (1966), and Chadha et al. (1973).

Investigation	n*	Examination 1		Examination 2		Examination 3	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Magill	63	5.28 mm	—	3.15 mm	—	3.83 mm	—
Ludwig	20	4.90 mm	—	2.30 mm	—	3.60 mm	—
Chadha et al.	30	4.72 mm	1.85	3.05 mm	1.15	3.44 mm	0.99
Present study	30	3.48 mm	1.78	1.58 mm	0.84	3.00 mm	1.57

* The number of cases examined in which premolars had been extracted.

overbite. The absence of a significant correlation between the posttreatment changes in overbite and the length of the posttreatment interval raises the possibility that the posttreatment changes occurred at an early stage of this period.

Simons and Joondeph (1973) studied changes in overbite in 70 subjects with various malocclusions treated with the Edgewise technique. Fifty-one extraction and 19 non-extraction cases were studied in which retention appliances had not been worn for at least ten years. Their findings revealed that, in general, patients with an initial deep overbite also had a deep overbite ten years postretention. In addition, it was shown that treatment and posttreatment changes were related. Further Simons and Joondeph found that patients with an initial deep overbite maintained the greatest amount of overbite correction. The findings of the present investigation confirm their results.

Simons and Joondeph speculated that overcorrection of overbite might lead to a more satisfactory result. In the present study a weak relationship was found between the amount of overbite change during treatment and the overbite at the final examination. This finding is not inconsistent with the speculation of the above mentioned authors.

Magill (1960), Ludwig (1966) and Chadha et al. (1973), investigated treatment results of overbite correction in cases treated with the Edgewise technique and extraction of four premolars.

To facilitate comparison of the results of the present investigation, with these three studies, the data are listed in Table 3.4. A comparison of the data, show that our cases have smaller overbites at the end of treatment than those of the other three studies. Several factors may be responsible for this difference. Such factors are, the difference in selection of samples and measuring technique. Another, is the difference in treatment objectives; in the Begg technique, the aim in the treatment of deep overbite is to obtain an end to end relationship of the incisors at the end of treatment.

The results at the final examination again show differences between the four samples. The value of the mean overbite of the present investigation is the lowest and the mean overbite in the Magill investigation is the highest. It should however be noted, that this order was also found at the first examination and that differences in the results are small. This suggests that if the large number of variables in the different investigation are taken into account, there is little difference between the final results of the present investigation and the three studies reviewed. Magill (1960) also compared the ten largest and the smallest overbites in his material. His results are much like those of the present study: small overbites tend to be relatively larger at the final examination and large overbites tend to be large at the final examination, although they decrease by a greater amount.

In conclusion, it may be stated that in the posttreatment period a partial relapse of overbite correction generally occurs. Furthermore, the final results appear to be similar, irrespective of the treatment method used. Finally, the findings of the present investigation, showed that in some cases of deep initial overbite there was relative stability in the posttreatment period. Whilst, in others the relapse was quite large, although, in all cases except one the final overbite in this group (OBI) was less than the initial overbite.

vertical position of mandibular and maxillary incisors and occlusal plane inclination

4.1. Introduction

There are conflicting reports in the literature on changes during treatment in the vertical positions of the mandibular molars and incisors, when a decrease in overbite (bite opening) takes place in the Begg technique. These results can be divided into three main categories:

1. Begg (1965), Begg and Kesling (1969) and Sims (1971) found that mandibular incisor intrusion usually occurs and that molar extrusion is minimal.
2. Swain and Ackerman (1969) observed that mandibular incisor eruption is prevented during treatment. They contend that overbite correction is due mainly to an increased eruption of mandibular molars. Grano (1971), also found that the vertical position of mandibular incisors was stable and that a vertical movement of molars occurred.
3. James (1968), Williams (1968) and Bijlstra (1969) found that overbite correction during treatment was due to mandibular incisor intrusion and mandibular molar extrusion.

The aim of this part of the study was to investigate the vertical changes in position of mandibular and maxillary incisors and inclination of occlusal plane. Additionally, to examine these changes in relation to overbite.

The occlusal plane was evaluated using the Björk structural method of superimposing mandibles. This superimposition technique, contrary to other techniques, enables an evaluation of the changes, with minimal interference from those due to facial growth or treatment.

Figure 4.1. The method used to determine the change in inclination of the occlusal plane (OP). The inclination of the occlusal plane is measured relative to the ramal plane at the initial examination (RP1), when mandibles are superimposed on the natural reference structures. The solid line represents the mandible at the initial examination and the dotted line at the final examination.

4.2. Measurements

For details of the cephalometric techniques and the glossary of cephalometric landmarks and planes see Chapter 2.3. The measurements are illustrated in Figure 3.1. and 4.1.

- Is-PP The shortest distance from the incisal edge of the most anterior maxillary incisor (Is) to the palatal plane (PP).
- li-MP The shortest distance from the incisal edge of the most anterior mandibular incisor (li) to the mandibular plane (MP),
- OP_{x1-x2}.RP1 The change in inclination of the occlusal plane (OP) determined by the difference between the inclination of OP_{x1} and OP_{x2}, measured relative to the ramal plane at the first examination (RP1). The ramal plane serves only as a reference structure. An increase in the occlusal plane inclination denotes a backward rotation of the occlusal plane and a decrease denotes a forward rotation of the occlusal plane.

The changes of the occlusal plane were examined in 21 subjects, the distances Is-PP and li-MP in 30 subjects.

Table 4.1. mean values and distribution of individual values of treatment, posttreatment, and net changes of the vertical positions of the incisors and the occlusal plane.
Significance level: $n=30$, $t \geq 2.750$, $P \leq 0.01$, $n=21$, $t \geq 2.086$, $P \leq 0.05$; $t \geq 2.845$, $P \leq 0.01$.

Variable	n	Mean	S.D.	Range	t	Sign
Is-PP 2-1	30	1.50 mm	1.62	-1.3 4.7	5.081	$P < 0.01$
Is-PP 3-2	30	1.50 mm	1.05	-0.4 3.5	7.882	$P < 0.01$
Is-PP 3-1	30	3.01 mm	1.53	0.0 6.1	10.735	$P < 0.01$
li-MP 2-1	30	-1.02 mm	1.97	-5.9 2.4	2.836	$P < 0.01$
li-MP 3-2	30	2.38 mm	1.31	0.3 5.1	9.941	$P < 0.01$
li-MP 3-1	30	1.36 mm	2.34	-2.7 5.9	3.173	$P < 0.01$
OP 2-1.RPI	21	4.48°	3.98	-4.5 9.8	5.270	$P < 0.01$
OP 3-2.RPI	21	-1.80°	3.14	-8.8 5.2	2.686	$P < 0.05$
OP 3-1.RPI	21	2.68°	3.34	-6.4 9.4	3.774	$P < 0.01$

4.3. Results

4.3.1. Mean values and distribution of individual values

The statistical data on the measurements made are shown in Table 4.1.

The distance from the maxillary incisal edge to the palatal plane. This distance was found to increase significantly in the treatment and posttreatment periods. The mean increase in the treatment period was 1.50 mm, standard deviation 1.62 mm, the individual values ranged from a decrease of 1.3 mm to an increase of 4.7 mm. In the posttreatment period the mean increase was 1.50 mm with a standard deviation of 1.05 mm, the range was from -0.4 mm to 3.5 mm. A mean net increase between the first and third examination of 3.01 mm, standard deviation 1.53 mm was found to occur, and the range was from 0.0 to 6.1 mm.

The distance from the mandibular incisal edge to the mandibular plane. This variable differs from that of the maxillary incisor in that during treatment a significant mean decrease of 1.02 mm with a standard deviation of 1.97 mm occurred. The largest decrease was 5.9 mm and the largest increase was 2.4 mm. In the posttreatment period a mean increase of 2.38 mm with a standard deviation of 1.31 mm was found to have taken place. The range was from 0.3 to 5.1 mm. The mean net increase was 1.36 mm with a standard deviation of 2.34 mm and a range from -2.7 mm to 5.9 mm.

Occlusal plane. A significant mean backward rotation of the occlusal plane of 4.48° , standard deviation 3.98° and a range of -4.5° to 9.8° occurred during treatment. A slight mean forward rotation in the posttreatment period of 1.80° with a standard deviation of 3.14° and range from -8.8° to 5.2° was found. It was found that a significant mean backward rotation of the occlusal plane of 2.68° , standard deviation 3.34° and a range of -6.4° to 9.4° , had occurred between the first and third examinations.

4.3.2. Relationship between changes of occlusal plane inclination and vertical changes in position of mandibular molars and incisors.

The occlusal plane was defined as the line drawn through the incisal edge of the most anterior mandibular incisor and the disto-buccal cusp of the mandibular first molar. It follows that a change in occlusal plane inclination as measured by the structural method of superimposition may be due to a change in: a. the position of the first molar; b. the position of the mandibular incisal edge; c. a combination of both.

To investigate the site at which the changes of occlusal plane inclination take place in the individual subjects the coordinates representing the superimposed mandibles were plotted and the graphical representation of each subject was examined, to determine the relative vertical changes in incisors and molars. These vertical changes were evaluated with reference to the occlusal plane at the first examination. A table (Table 4.2.) was set out showing the individual vertical changes of the teeth and the findings were ordered according to the corresponding change in occlusal plane. The change in overbite for each individual was also included. An arrow indicates an occlusal positioning ($\uparrow$) or intrusion ($\downarrow$) of an incisor or molar. A small arrow ($\uparrow$) indicates that the change in the position of incisor or molar is relatively less than the corresponding change in the position of molar or incisor.

Changes during the treatment period. In 18 cases a backward rotation of the occlusal plane took place and in three cases a forward rotation. Rotation of the occlusal plane depends on the relative changes in position of incisors and molars. Therefore an interpretation of the observed changes requires a further analysis of vertical movements of incisors and molars. Three different responses are possible: 1. intrusion; 2. no positional change; 3. occlusal positioning. The second possibility may be interpreted as prevention of eruption. Occlusal positioning may be due to eruption which normally occurs or to an extrusion which is due to effects of treatment or a combination of both. Furthermore occlusal positioning as well as intrusion may vary in amount.

All three types of response were found for the mandibular incisors: five cases showed various amounts of occlusal positioning; eleven cases showed various

Table 4.2. The table shows individual changes in overbite, occlusal plane measured by the structural method of superimposition (OP_{x₁-x₂}RP1) and the relative vertical changes of the mandibular incisor (Ii) and first molar (D), in the treatment period and following treatment. The findings are ordered according to the change in occlusal plane of the initial examination. An arrow indicates either molar or incisor, extrusion (↑) or intrusion (↓). A small arrow (†) indicates that the change in incisor or molar is relatively less than the corresponding change in position of molar or incisor. A negative value indicates an occlusal plane inclination decrease, a positive value an increase (relative to the ramal plane). Using the coordinates of the registered landmarks, changes in the molar and incisor position were determined by inspection of the graphical representation of the superimposed mandibles.

Case	Occusal plane (degrees)		Incisor		Molar		Overbite (mm)	
	2-1	3-2	2-1	3-2	2-1	3-2	2-1	3-2
3614	-5	-2	↑	↑	↑	↑	-0.2	1.7
4697	-3	2	↑	—	↑	↑	1.1	0.1
5170	-1	5	↑	—	↑	↑	1.0	-0.9
5013	1	0	↑	↑	↑	↑	-1.1	1.7
3430	2	1	↓	↑	↓	↑	-1.5	2.7
3473	2	-1	↑	↑	↑	↑	-0.6	0.5
3269	2	-2	—	↑	↑	↓	-3.7	2.3
5074	3	-2	↓	↑	↑	↑	-1.7	0.9
4657	4	-5	↓	↑	↑	↑	-1.8	1.8
3679	5	-2	↓	↑	↑	↑	1.6	-0.5
4923	6	-3	↓	↑	↑	↑	-1.4	1.3
3724	6	1	—	↑	↑	↑	-1.9	1.5
5211	6	0	—	↑	↑	↑	-2.7	0.9
4251	6	0	↓	↑	↑	↑	-5.5	0.7
4246	6	-4	↓	↑	↑	↑	-2.9	2.8
4445	7	-5	—	↑	↑	—	-1.3	1.5
5076	7	1	↓	↑	↑	↑	-2.4	1.5
3170	9	-9	—	↑	↑	↓	-2.0	2.7
3470	9	-2	↓	—	↑	↓	-0.9	-1.3
4243	10	-5	↓	↑	↑	↑	-4.1	4.7
4799	10	-7	↓	↑	↑	↓	-3.6	2.4

Figure 4.2. Examples of vertical changes in incisor position during treatment: 1. intrusion; 2. no positional change; 3. occlusal positioning. Mandibles superimposed on natural reference structures.

amounts of intrusion; in five cases no positional change was observed. An example of each type is illustrated in Figure 4.2. In contrast to the variability in the incisor response, the molar response was uniform. In 20 cases mandibular molars were more occlusally positioned. One case, however, responded differently. In this case (3430) the molars would appear to have been intruded. Relatively little vertical movement had occurred in this case, but the crown of the tooth had been tipped distally during treatment resulting in an apparent molar intrusion. Backward rotation of the occlusal plane was due to a more occlusal positioning of the molars relative to the incisors. In contrast to the backward rotation a forward rotation was found to be due to a greater occlusal positioning of the incisors relative to the molars.

The relationship of the occlusal plane rotation to the change in overbite may be investigated by inspection of Table 4.2. In three cases the overbite increased during treatment. In two of these cases the occlusal plane rotated forward, while in the remaining case a backward rotation occurred. At the other end of the scale a tendency was found for large overbite decreases (bite opening) to occur in association with large backward rotations of the occlusal plane. Furthermore large backward rotations were associated with incisor intrusion or no positional change whereas forward rotations were associated with occlusal positioning of incisors.

Changes in the posttreatment period. Inspection of Table 4.2. shows that a backward rotation of the occlusal plane occurred in five cases. In 13 cases a forward rotation was found and in three cases no change was observed. Of these 13 cases, twelve showed a backward rotation during treatment. In one case a forward rotation also occurred during treatment. Of the five cases in which a backward rotation was observed, three also showed such rotation during treatment; while the other two showed a forward rotation during treatment. In the three cases in which no

change was observed in the posttreatment period a backward rotation was found during treatment.

Irrespective of the treatment response of the mandibular incisors, an eruption took place in the posttreatment period, with the exception of three cases in which no change was noted. Of these three cases, two had shown an occlusal positioning during treatment and in the remaining case an intrusion had occurred. In four cases a molar intrusion was observed in the posttreatment period, in one case no change was found and in 16 cases eruption was found to take place. In the cases in which intrusion or no change was found an extrusion would appear to have occurred during treatment. This apparent intrusion of the molars may be termed relapse.

In the five cases in which backward rotation of the occlusal plane was observed, the molars were relatively more occlusally positioned than the incisors. In the 13 cases with forward rotation the incisors were more occlusally positioned than the molars and in four cases molars were found to have been intruded in the posttreatment period. It is likely that a relapse of the occlusal plane rotation occurred in all those cases in which the posttreatment changes were opposite to those which occurred during treatment.

The relationship between changes of overbite to the changes in occlusal plane inclination in the posttreatment period is not fully clarified by an inspection of Table 4.2. A large increase in overbite occurred in cases in which both small and large rotations of the occlusal plane were observed. However, a predominance of large overbite increases were associated with a forward rotation of the occlusal plane. Finally, no obvious relationship was noticeable between the positional changes in molars, incisors and the overbite.

4.3.3. Correlations

To evaluate the relationship between changes in overbite to changes in the occlusal plane, the distance from the incisal edge of the most anterior mandibular incisor to the mandibular plane and the distance from the incisal edge of the most anterior maxillary incisor to the palatal plane, a number of correlation coefficients were calculated (Table 4.3.).

Changes during the treatment period. The correlation coefficient between the changes of overbite and the distance from the mandibular incisal edge to the mandibular plane was found to be significant, as was that between changes of overbite and occlusal plane inclination. The significance of the correlation coefficients confirms the impression gained by inspection of Table 4.2. The correlation between the changes in overbite and the distance from the maxillary incisor edge to the palatal plane was not significant.

Table 4.3. Correlation coefficients relating overbite changes during and following treatment to occlusal plane and incisor changes and their interrelationships.

Significance levels: $n=30$, $r \geq 0.362$, $P \leq 0.05$; $r \geq 0.463$, $P \leq 0.01$. $n=30$, $r \geq 0.433$, $P \geq 0.05$; $r \geq 0.549$, $P \leq 0.01$.

Variable	Variable	n	r	Sign
overbite 2–1	Is-PP 2–1	30	0.268	NS
	Ii-MP 2–1	30	0.559	$P < 0.01$
	OP 2–1.RP1	21	–0.514	$P < 0.05$
overbite 3–2	Is-PP 3–2	30	0.293	NS
	Ii-MP 3–2	30	0.309	NS
	Op 3–2.RP1	21	–0.517	$P < 0.05$
overbite 3–2	Is-PP 2–1	30	–0.242	NS
	Ii-MP 2–1	30	–0.234	NS
	OP 2–1.RP1	21	–0.241	NS
OP 2–1.RP1	Is-PP 2–1	21	0.294	NS
	Ii-MP 2–1	21	–0.561	$P < 0.01$
OP 3–2.RP1	Is-PP 3–2	21	–0.047	NS
	Is-MP 3–2	21	–0.325	NS
Is-PP 2–1	Is-PP 3–2	30	–0.407	$P < 0.05$
Ii-MP 2–1	Ii-MP 3–2	30	–0.240	NS
OP 2–1.RP1	OP 3–2.RP1	21	–0.581	$P < 0.01$

Changes in the posttreatment period. Correlation coefficients relating to post-treatment changes in overbite were evaluated. The posttreatment changes in overbite were not found to be associated with posttreatment changes in the distance from the maxillary incisal edge to the palatal plane or the mandibular incisal edge to the mandibular plane.

The correlation coefficient between posttreatment changes in overbite and occlusal plane inclination was found to be significant. This correlation coefficient, when evaluated with the mean values and standard deviations, indicates that a large, or respectively a small increase in overbite tended to be associated with a forward rotation or respectively a backward rotation of the occlusal plane. The correlation coefficients between the treatment changes of the occlusal plane inclination, incisor positions and the posttreatment changes in overbite were calculated. They were not found to be significant.

Finally, the correlation coefficient between the treatment and posttreatment

changes of occlusal plane was calculated. The correlation was found to be significant and confirms the impression gained by the inspection of Table 4.2. The correlation coefficient between treatment and posttreatment changes of the distance from the maxillary incisor edge to the palatal plane was significant. When evaluated with the mean values and standard deviations, it indicates that there was a tendency for large or respectively small treatment increases to be associated with small, or respectively large posttreatment increases. The correlation between treatment and posttreatment changes of mandibular incisor position was not significant.

4.4. Discussion

A distinction between the effects of treatment and normal growth changes is difficult to make when examining occlusal positioning of incisors or molars without the use of a relevant control group. The investigators referred to in the introduction to this chapter were generally unable to distinguish between the effects of treatment and normal growth. Furthermore, little attention was paid to the individual response. Using metallic implants in the mandible as reference structures to superimpose mandibles of annual lateral radiographs of 21 untreated subjects, Björk and Skieller (1972) studied mandibular growth and its relation to occlusal development. The longitudinal study covered a six year adolescent period. In all cases studied, the eruption of incisors and molars was found to occur. In cases with forward mandibular rotation, the molar eruption was greater than that of incisors, resulting in a backward occlusal plane rotation. In cases with a backward mandibular rotation, incisor eruption was greater than molar eruption.

Mandibular incisors. In the present study considerable individual variability in incisor response during treatment was found. A significant intrusion of incisors in the mandibular arch during treatment has been shown to take place, an intrusion which was found to be related to the decrease of overbite. However, it has also been shown that eruption may be prevented and that in a number of cases mandibular incisor eruption during treatment occurred when overbite changes were small. Thus it may be stated that intrusion, the prevention of eruption or eruption of mandibular incisors may occur during treatment, the nature of the change being related to the change in overbite.

In the posttreatment period an occlusal positioning of the mandibular incisors or no positional change was found. The occlusal positioning may be either due to eruption or to an extrusion which is possibly caused by the connective tissue response to treatment. The occlusal positioning showed no apparent relationship to overbite increase (deepening of the overbite). Also no correlation was found between the treatment and posttreatment changes of the distance of the incisal

edge of the mandibular incisor to the mandibular plane, and although it indicates that there is no relapse tendency of the intruded mandibular incisors, vertical growth in the posttreatment period may obscure an incisor relapse.

Mandibular Molars. The findings on the molar changes are more difficult to interpret since, while it is clear that molars were generally more occlusally positioned during treatment, the measurement does not distinguish between extrusion, or the effects of treatment and eruption, or normal growth.

In the present study molars were generally more occlusally positioned both during and after treatment, an apparent normal occurrence. However, in the post-treatment period molar intrusion was ascertained in four cases. In these cases in which molar intrusion was found it is likely that they were extruded during treatment. It may be concluded that relapse had occurred in these cases. In addition an intrusion may have been ascertained in other cases, had the final examination taken place at an earlier stage, as growth of the alveolar process subsequent to an intrusion may mask the initial intrusion. In the remaining cases in which no intrusion was found in the posttreatment period, it is likely that eruption occurred during treatment as part of the normal developmental process. There was no obvious relationship between molar changes and changes in overbite during or following treatment.

Occlusal plane. In relation to incisors, molars were more occlusally positioned in 18 cases during treatment. This resulted in a backward rotation of the occlusal plane. Of these 18 cases, twelve cases had a forward rotation in the posttreatment period. This is apparently a relapse of occlusal plane rotation. The relapse was due to a greater occlusal positioning of the incisors relative to the molars. It resulted from an eruption or no positional change of the mandibular incisors in combination with a relatively smaller eruption of the molars or their intrusion. In the remaining six cases in which a backward rotation occurred during treatment no rotation or a slight backward rotation was observed after treatment. It appears that in these cases the amount of rotation during treatment was desirable, in that it was maintained in the posttreatment period and it seems that forward rotation would normally take place in these cases. Of the three cases in which a forward rotation occurred during treatment, two cases had a forward rotation in the posttreatment period. In one case the direction of rotation was the same in the posttreatment period.

A relationship was found between the occlusal plane rotation and overbite changes during treatment. A large overbite decrease was associated with a large backward rotation of the occlusal plane. This finding indicates a graduated response of the occlusal plane during treatment, dependent on the size of the overbite. Taking into consideration that occlusal plane rotation is due to a combination of factors, it may be concluded that molar and incisor changes contribute to the

changes in overbite during treatment, the extent of their response being associated with the extent of the overbite correction.

In contrast, a forward rotation following treatment was related to an overbite decrease. It appears that it is a combination of molar and incisor changes which were related to an overbite relapse in the posttreatment period. The significance which may be attributed to these factors is not great, as, the correlation coefficient expressing the relationship of posttreatment overbite changes and occlusal plane rotation, although significant, is relatively low. It therefore appears that other factors besides those which cause changes in the occlusal plane also influence the overbite.

Our findings are not in agreement with the findings of other recent studies. Swain and Ackerman (1969) reported that relapse of overbite correction in Begg treated cases was caused by additional eruption of mandibular incisors. They also found that mandibular molars do not intrude after treatment but continue to erupt and that incisor eruption was greater than that of the molars. Schudy (1973) and Simons and Joondeph (1973), observed incisor intrusion to be related to posttreatment incisor eruption and a concomitant overbite relapse. The present findings do not lead to the conclusion that relapse of overbite is due to additional eruption of mandibular incisors; rather that a greater eruption of mandibular incisors relative to an intrusion or eruption of the mandibular molars is a factor in overbite relapse.

Maxillary incisors. Intrusion of maxillary incisors was generally not found to occur during treatment. In the present investigation there was no apparent relationship between the changes in overbite and vertical changes in position of the maxillary incisors. This lead to the conclusion that treatment changes in overbite are mainly due to changes in the mandibular dental arch. A number of factors may influence the vertical changes in the position of the maxillary central incisors. In subjects with protruding incisors, the action of reducing this protrusion would tend to cause an increase in the vertical dimension. In addition the possibility that Class II intermaxillary elastics or auxilliary root torquing arch wires may cause extrusion of maxillary incisors should be considered. An indication that this may have occurred is to be found in the inverse relationship between treatment and posttreatment changes of the distance from the maxillary incisal edge to palatal plane. These findings may indicate that an extrusion of incisors during treatment is followed by an intrusion of incisors after treatment. That the intrusion is not evident may be due to an increase in height of the alveolar process being greater than the intrusion.

It is apparent that although overbite was frequently found to increase after treatment the factors which contribute to these changes are not all evident. Other dental factors, changes in facial dimensions or actual rotations of the mandible may cause a posttreatment increase. It is likely that factors which cause the initial

overbite are the same factors which contribute to an increase in overbite following treatment. In subsequent chapters other factors which may be related to the overbite will be investigated.

In conclusion it may be stated that during treatment with the Begg technique, the vertical changes in the position of the mandibular incisors were modified depending on the extent of the overbite changes. An intrusion of mandibular incisors was related to a large overbite decrease, while eruption of the mandibular incisors occurred when overbite changes were small. The mandibular first molars were more occlusally positioned during treatment and although it is difficult to make a distinction between extrusion and eruption it appears that in some cases the term extrusion is applicable. Thus, our findings indicate that, a variety of different responses occurred in the treatment period. Probably due to individuality of the malocclusions and the application of the technique. Mandibular incisor eruption in the posttreatment period was found to be relatively greater than that of the molars and in some cases molar intrusion occurred. This combination appears to be a factor in the cause of overbite relapse.

5.1. Introduction

The reduction of abnormal overjet is an important objective in the treatment of Class II division 1 malocclusions as these malocclusions are often associated with a convex facial appearance and incompetent lip function due partly to the large overjet.

Moyers (1973) refers to the many factors which contribute to the difficulty of treating a Class II malocclusion. He states that the malocclusion is most difficult to treat well when the distoclusion and sagittal jaw discrepancy are combined with a lack of arch space to align all teeth, a vertical jaw discrepancy and abnormal musculature.

The aim of this section of the study was to evaluate the changes in overjet during treatment and posttreatment periods and to examine the relationship between overjet and overbite.

5.2. Measurement

The method of measurement is illustrated in Figure 5.1.

OJ Overjet, was defined as the distance between the incisal tip of the most anterior maxillary incisor (Is) and the incisal tip of the most anterior mandibular incisor (Ii), measured perpendicular to the facial plane (NPg).

5.3. Results

5.3.1. Mean values and distribution of individual values

Mean values and distribution of individual values are shown in Table 5.1.

Figure 5.1. Method used to determine the overjet (OJ), inclination of maxillary incisor line (ILS) relative to the cranial base (SN), (1LS.SN), inclination of mandibular incisor line (ILi) relative to the mandibular plane (MP), (ILI.MP), and the interincisal angle (ILS.ILi).

Table 5.1. Mean values and distribution of individual values of overjet.
Significance level: $n=30$, $t \geq 2.756$, $P < 0.01$.

Variable	n	Mean	S.D.	Range		t	Sign
overjet 1	30	7.54 mm	2.84	1.6	12.4	6.200	$P < 0.01$
overjet 2—1	30	-5.04 mm	2.95	-10.0	0.2		
overjet 2	30	2.50 mm	0.66	1.3	4.0	4.023	$P < 0.01$
overjet 3—2	30	1.04 mm	1.42	- 1.1	5.9		
overjet 3	30	3.54 mm	1.15	1.8	7.2	8.643	$P < 0.01$
overjet 3—1	30	-4.00 mm	2.53	- 9.1	1.1		

The initial mean overjet for the sample was 7.54 mm, with a standard deviation of 2.84 mm. The smallest individual overjet was 1.6 mm and the largest was 12.4 mm. A significant mean decrease in overjet of 5.04 mm with a standard deviation of 2.95 mm occurred during the treatment period. The largest decrease was 10.1 mm and the largest increase 0.2 mm.

At the end of treatment considerable uniformity for the values of overjet was found (Mean 2.50 mm standard deviation 0.66 mm and a range of 1.3 to 4.0 mm). In the posttreatment period a significant mean increase of 1.04 mm, standard deviation of 1.42 mm and a range of -1.1 mm to 5.9 mm was found.

At the final examination, the mean overjet was 3.54 mm, and the standard deviation was 1.15 mm. The smallest overjet was 1.8 mm. and the largest 7.2 mm. A significant mean decrease in overjet between initial and final examinations of 4.00 mm, standard deviation 2.53 took place. The largest decrease was 9.1 mm. and the largest increase was 1.1 mm.

To compare the treatment of small and large overjets, the sample was subdivided on the basis of the overjet at the initial examination. Two separate groups, Group OJI and Group OJs were formed. Group OJI contained the ten largest overjets. They were all Class II division 1 malocclusions. Group OJs contained the ten smallest overjets. They were Class I or borderline cases. Table 5.2 shows the mean values and distribution of individual values. The individual changes are illustrated in Figure 5.2.

The treatment of overjet would appear to be equally effective in both groups as the mean difference between the two groups at the end of treatment was not significant.

Although the mean changes of overjet in the posttreatment period were found to differ significantly, the mean difference was small. The individual variability of posttreatment changes was larger in Group OJI. In this group the mean value was 1.77 mm and standard deviation 2.04 mm. An increase of 5.9 mm. was observed in one case, while in another a decrease of 1.1 mm occurred. In Group OJs the mean was 0.37 mm and standard deviation 0.78 mm. The changes ranged from a decrease of 0.8 mm to an increase of 1.5 mm.

At the final examination the mean difference between the two groups was significant. The mean overjet of Group OJI was 4.29 mm standard deviation 1.45 mm and the range was from 2.3 mm to 7.3 mm. In Group OJs, the mean value was 3.06 mm, standard deviation 0.78 mm and range from 2.1 to 4.5 mm. The mean difference of the net changes was significant. In group OJI, the mean decrease was 6.41 mm and the standard deviation 1.54 mm. The largest decrease was 9.1 mm and the smallest 4.0 mm. In group OJs, the mean decrease was 1.40 mm and standard deviation 1.65 mm. The largest decrease was 3.4 mm and the largest increase 1.1 mm.

Figure 5.2. Changes in overjet occurring during the treatment and posttreatment periods in Group OJI (largest initial overjets) and Group OJs (smallest initial overjets).

Table 5.2. Values of overjet for the two groups containing the initial ten largest overjets (Groups OJI, Class 11, division 1) and the initial ten smallest overjets (Group OJs, Class 1).

Significance levels: $n=20$, $t \geq 2.101$; $P < 0.05$; $t \geq 2.878$, $P < 0.01$.

Variable	Group OJI Largest overjets, n=10				Group OJs Smallest overjets, n=10					
	Mean	S.D.	Range		Mean	S.D.	Range			
	t	Sign								
overjet 1	10.70 mm	1.06	9.1	12.4	4.46 mm	1.50	1.6	6.1	10.814	P<0.01
overjet 2-1	-8.19 mm	1.54	-10.1	-5.4	-1.78 mm	1.41	-4.1	0.3	9.653	P<0.01
overjet 2	2.51 mm	0.84	1.6	4.0	2.68 mm	0.43	1.9	3.2	0.562	NS
overjet 3-2	1.77 mm	2.04	-1.1	5.9	0.37 mm	0.81	-0.8	1.5	2.031	NS
overjet 3	4.29 mm	1.45	2.3	7.3	3.06 mm	0.78	2.1	4.5	2.358	P<0.05
overjet 3-1	-6.41 mm	1.54	-9.1	-4.0	-1.40 mm	1.65	-3.4	1.1	6.976	P<0.01

Table 5.3. Correlation coefficients calculated between values of overjet.
Significance level: $n=30$, $r \leq 0.363$, $P \leq 0.05$; $r \geq 0.464$, $P \leq 0.01$.

Variable	Variable	n	r	Sign
overjet 1	overjet 3	30	0.453	$P < 0.05$
overjet 2—1	overjet 3—2	30	−0.517	$P < 0.01$
	overjet 3	30	−0.468	$P < 0.01$
overjet 3—2	posttreatment interval	30	0.123	NS

An inspection of Figure 5.2 shows that in Group OJ1 (Class II division 1), a total relapse was in no instance evident. Furthermore, in this group, the considerable variability of changes during the posttreatment period and the large net decrease in individual cases is notable.

5.3.2. Correlations

To determine the relationships between the values of overjet, a number of correlation coefficients were calculated. They are shown in Table 5.3.

The correlation coefficient between initial and final overjet was significant. When evaluated with the mean values and standard deviations, it appears that a large or respectively a small overjet at the initial examination tends to have a large, respectively small overjet at the final examination. It is however clear that the final magnitude of the overjet is considerably less than at the initial examination.

The correlation coefficient between changes in overjet during the treatment and posttreatment periods was significant. When considered with the mean values and standard deviations, it appears that there was a tendency for a large or respectively a small decrease during the treatment period to be associated with a large or respectively a small increase in the posttreatment period. The posttreatment increases, however, were generally small.

Changes in overjet during the treatment period and the final overjet were found to be significantly correlated. When the correlation coefficient is appraised with the means and standard deviations, it seems that a large or respectively a small decrease during the treatment period tends to be associated with a large or respectively a small overjet at the final examination.

No significant relationship between the changes during the posttreatment period and its duration was found.

Table 5.4. Correlation coefficients calculated between overbite and overjet.
Significance levels; $n=30$, $r \geq 0.363$, $P \leq 0.05$; $r \geq 0.464$, $P \leq 0.01$.

Variable	Variable	n	r	Sign
overjet 1	overbite 1	30	0.378	$P < 0.05$
overjet 2–1	overbite 2–1	30	0.508	$P < 0.01$
overjet 3–2	overbite 3–2	30	0.369	$P < 0.05$
overjet 3	overbite 3	30	0.225	NS

5.3.3. Relationship of overjet to overbite

The correlation coefficients relating overjet to overbite are shown in Table 5.4.

The relationship between initial overbite and overjet was calculated by means of the correlation coefficient. It was found to be significant. When evaluated with the mean values and standard deviations, this indicates that a large or small overjet was associated with a large or small overbite, respectively.

The correlation coefficient between changes of overbite and overjet during treatment was significant. The correlation coefficient, when considered with the respective mean changes and standard deviations, indicates that a large decrease in overjet tends to be associated with a large decrease in overbite. A similar relationship exists for small changes.

The correlation coefficient between changes of overbite and overjet in the post-treatment period was significant. When evaluated with the means and standard deviations, this denotes a tendency for an increase in overbite to occur with an increase in overjet in the posttreatment period.

Finally, the correlation coefficient between the final values of overbite and overjet was evaluated. The correlation coefficient was not found to be significant. The scatter diagram (Figure 5.3) illustrates the relationship of the overbite to overjet for individual patients at the final examination. The points are widely spread and no particular relationship is evident. However, if the points denoting the large overjets are inspected it can be seen that large overjets may occur with small or large overbites. Likewise a large overbite may occur in combination with a small overjet or a large overjet. Therefore, there are three combinations of the incisal relationship at the final examination in which large relapse takes place: 1. a large overjet and a small overbite: 2. a large overjet and a large overbite: 3. a small overjet and a large overbite.

Figure 5.3. Scatter diagram illustrating the distribution of points representing individual values of overbite and overjet at the final examination. A point on the Z axis indicates that overbite and overjet in an individual case are of the same value. A large overjet and a small overbite is symbolised by a ■, a large overjet and a large overbite by a ○, and a small overjet and a large overbite by a ▲.

5.4. Discussion

Irrespective of the magnitude of the overjet at the start of treatment, considerable reductions occurred during the treatment period and the overjet was apparently reduced to a minimum in all cases. This is not surprising because one of the primary goals of the Begg therapy is the maximal reduction of overjet and overbite. Furthermore, the cases used for the study were selected on the basis of the success of the therapy at the end of the treatment period. The changes during the posttreatment period are of greater interest as the response is more variable and hence less predictable. The overjet was relatively stable in the posttreatment period in a large number of cases. However, in the subjects which had large initial overjets, the

Table 5.5. A comparison of different investigations of treatment of overjet.

Investigation	n	Examination 1		Examination 2		Examination 3	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Johannesen, 1972	26	9.27 mm	2.13	2.76 mm	0.86	3.87 mm	1.38
Chadha et al., 1973	30	5.02 mm	3.54	2.19 mm	1.44	2.48 mm	0.88
Present study	30	7.54 mm	2.82	2.50 mm	0.66	3.54 mm	1.15
Present study OJl	10	10.7 mm	1.1	2.5 mm	0.8	4.3 mm	1.5
Present study OJs	10	4.5 mm	1.5	2.6 mm	0.4	3.1 mm	0.7

results were variable. In some of these cases the overjet was relatively stable while in others relapse occurred although in no instance to the original situation and the resultant net decrease in overjet in this group was substantial.

Studies of changes in overjet during the treatment and posttreatment periods were made by Chadha et al. (1973), and Johannesen (1972). Their findings and those of the present investigation are set out in Table 5.5.

Chadha et al. (1973), investigated the changes of overjet in the treatment and posttreatment periods in 30 subjects treated using the Edgewise technique. Their findings show that the mean posttreatment changes were small. In addition, they noted a return of the overjet to the original value in some cases. A further comparison can be made between their findings and the findings of the smallest overjet in the present investigation. The mean values would appear to be similar if the differences in measuring techniques are taken into account. Unfortunately they did not identify the cases which showed the overjet relapse; thus a comparison on an individual basis is not possible.

Results of the treatment of Class 2 division 1 malocclusions were studied by Johannesen (1972). Twenty six Class II division 1 cases were studied, all having an overjet larger than 7 mm at the start of treatment. Diverse types of appliances were used to perform both tipping and bodily movements. The values of overjet were similar to those of the present investigation at the end of treatment. It is obvious that the similarity of results at the end of the treatment period is due to the criteria used in the selection of the different samples. Johannesen found that in the post-treatment period a small mean increase in overjet occurred.

The changes in the posttreatment period of the present investigation and that of Johannesen would seem to be similar as the mean increases in overjet were both found to be small. Johannesen found no relationship between the changes during the treatment period and those during the posttreatment period. This relationship was, however, significant for the present investigation. This indicates that the response of the individual patients in the two investigations was different. An

explanation for these contradictory findings may lie in our observation that changes in the posttreatment period were more variable and less predictable. In addition, the different treatment techniques employed in the two studies may have influenced the result.

The relationship between the overbite and overjet changes during treatment and posttreatment periods were not unexpected as the objectives of treatment were to reduce the overjet and overbite to a minimum. It was expected that some form of relapse should occur in the posttreatment period. The lack of an association between the final values of the overbite and overjet is due to the diversity of the individual posttreatment changes. The scatter diagram (Figure 5.3) showed three combinations of relapsed incisal relationship. Relapse of overbite would seem to be fairly predictable. Relapse of overjet is less predictable; since it frequently remains stable and when relapse occurred in cases with large initial overjet it did not relapse to the original situation.

The relationship of overjet to other variables will be discussed in subsequent chapters.

sagittal inclination of mandibular and maxillary incisors

6.1. Introduction

The axial inclination of the incisors in the sagittal plane is frequently altered during treatment. In addition to aesthetic effects which may result, the inclination of the incisors at the end of treatment is considered to be one of the factors associated with the stability of the treatment.

Riedel (1969), reviewed the literature on the problem of relapse. He concluded that: 1. tipping the incisors into a position too upright relative to each other may result in a relapse of overbite; 2. lower incisors should be placed upright over "basal bone" ($90^\circ \pm 5^\circ$ to the mandibular plane) to enhance the stability of the treatment. In addition, he expressed a preference for positioning mandibular incisors too far labially. Schudy (1973) maintained that a close relationship exists between overbite and the interincisal angle.

In this chapter, the changes in the sagittal inclination of the maxillary and mandibular incisors will be investigated. Furthermore, the relationship of these changes to the changes in overbite and overjet will be analysed.

6.2. Measurements

The method of measurement is illustrated in Figure 5.1. The definitions of the points and lines are given in Chapter 2.3.

ILi.MP The angle formed by the inclination of the mandibular incisor line (ILi) relative to the mandibular plane (MP).

ILs.SN The angle formed by the inclination of the maxillary incisal line (ILs) relative to the sella nasion plane (SN).

ILs.ILi The interincisal angle. The angle formed between the maxillary (ILs) and mandibular (ILi) incisal lines.

Table 6.1. Mean values and distribution of the individual values of the axial inclinations of the incisors.

Significance levels: $n=30$, $t \geq 2.045$, $P \leq 0.05$; $t \geq 2.756$, $P \leq 0.01$.

Variable	n	Mean	S.D.	Range		t	Sign
ILi.MP 1	30	95.72°	8.61	74	112	0.072	NS
ILi.MP 2-1	30	0.11°	8.27	-10	21		
ILi.MP 2	30	95.82°	8.90	79	117	1.891	NS
ILi.MP 3-2	30	-1.74°	5.07	-18	4		
ILi.MP 3	30	94.08°	8.61	80	113	1.393	NS
ILi.MP 3-1	30	-1.63°	6.42	-13	13		
ILs.SN 1	30	106.54°	7.74	82	118	6.389	P<0.01
ILs.SN 2-1	30	-10.67°	9.16	-31	6		
ILs.SN 2	30	95.86°	7.56	74	109	4.301	P<0.01
ILs.SN 3-2	30	3.57°	4.53	-3	20		
ILs.SN 3	30	99.44°	8.61	80	113	5.503	P<0.01
ILs.SN 3-1	30	-7.10°	7.09	-23	7		
ILs.ILi 1	30	121.76°	10.88	104	155	4.901	P<0.01
ILs.ILi 2-1	30	10.93°	12.21	-20	34		
ILs.ILi 2	30	132.69°	9.92	114	151	0.142	NS
ILs.ILi 3-2	30	0.17°	6.49	-18	14		
ILs.ILi 3	30	132.86°	9.14	116	149	6.300	P<0.01
ILs.ILi 3-1	30	11.10°	9.64	-10	23		

In the text, inclination of maxillary or mandibular incisor lines will be referred to as the maxillary or mandibular incisor inclination.

Mandibular incisor inclination relative to the mandibular plane was measured by the classical method rather than the Björk method for the following reasons: 1. seven of the nine cases in which the Björk method of superimposition was not used were 1. Class II division 1 cases and constituted seven of the ten cases of the group with the ten largest overjets. This made a comparison of Class II division 1 and Class I malocclusions difficult using this method: 2. the changes of mandibular inclination were small (Chapter 8) and therefore not of great influence on the measurement of the incisor mandibular plane angle.

6.3. Results

6.3.1. Incisor mandibular plane angle

The mean values and distribution of individual values are shown in Table 6.1.

Table 6.2. Group OJI consists of the ten cases with the largest overjets at the initial examination and Group OJs of the ten cases with the smallest overjets at the initial examination.

Significance levels: $n=20$, $t \geq 2.101$, $P \leq 0.05$; $t \geq 2.878$, $P \leq 0.01$.

Variable	Group OJI largest overjets, n = 10				Group OJs smallest overjets, n = 10				t	Sign
	Mean	S.D.	Range		Mean	S.D.	Range			
ILi.MP 1	96.05°	11.06	74	112	93.02°	8.48	85	106	0.686	NS
ILi.MP 2—1	6.29°	10.34	—1	21	—3.34°	4.47	—8	3	2.702	P<0.05
ILi.MP 2	102.34°	8.08	93	114	89.68°	6.67	80	99	3.818	P<0.01
ILi.MP 3—2	—4.23°	7.07	—18	3	—1.01°	2.98	—5	4	1.323	NS
ILi.Mp 3	98.11°	8.34	87	105	88.67°	5.88	81	98	2.924	P<0.01
ILi.MP 3—1	2.06°	6.36	—1	13	—4.35°	5.17	—12	4	2.474	P<0.05
ILs.SN 1	109.43°	3.46	104	114	101.22°	10.75	84	114	2.296	P<0.05
ILs.SN 2—1	—16.03°	8.73	—31	—2	—3.34°	8.93	—23	6	3.212	P<0.01
ILs.SN 2	93.40°	9.44	74	106	97.88°	7.49	98	107	1.177	NS
ILs.SN 3—2	4.96°	5.80	0	20	1.33°	4.28	—3	11	1.595	NS
ILs.SN 3	98.36°	5.95	87	109	99.21°	7.19	86	109	0.288	NS
ILs.SN 3—1	—11.07°	5.85	—19	2	—2.01°	6.76	—12	7	3.200	P<0.01
ILs.ILi 1	119.52°	9.08	104	134	129.12°	12.77	108	156	1.951	NS
ILs.ILi 2—1	9.69°	14.62	—5	22	7.83°	13.58	—10	35	0.295	NS
ILs.ILi 2	129.21°	10.61	117	151	137.02°	10.11	117	148	1.685	NS
ILs.ILi 3—2	1.48°	9.22	—18	14	1.84°	4.58	—7	11	0.122	NS
ILs. 3	130.69°	4.65	124	139	138.86°	9.71	121	150	2.400	P<0.05
ILs.ILi 3—1	11.67°	9.96	—10	23	9.67°	11.08	—8	28	0.317	NS

The mean inclination of the mandibular incisors relative to the mandibular plane was 95.72° at the start of treatment. The standard deviation was 8.61° and range from 74° to 112°. Seventy-four degrees indicates a retroclined incisor while 112° indicates a proclined incisor. Neither treatment nor posttreatment changes were significant. Of importance is the observation of a considerable individual variation in these changes.

At the final examination the mean incisor mandibular plane angle was 94.08°, standard deviation 8.61° and the individual values ranged from 80° to 113°. The mean change between initial and final examination was found to be not significant. However, the standard deviation of 6.42° indicates large individual variation. The largest increase (13°) which occurred was in a patient with a Class II division 1, in which the mandibular incisors were retroclined at the start of treatment. The largest decrease (13°) which occurred was in a Class II division 1 case in which the lower incisors became progressively more upright during and following treatment.

The correlation coefficient was calculated between treatment and posttreatment changes ($r=-0.630$, $P<0.01$) and found to be significant. It denotes a strong general

Figure 6.1. Change during the treatment and post treatment periods of the incisor mandibular plane angle in Group OJI (large initial overjets) and Group OJs (small initial overjets).

tendency for the changes which occur during the treatment period to be reversed in the posttreatment period.

To compare the incisor mandibular plane angle in Class II division 1 and Class I malocclusions, the sample was subdivided as described in Chapter 5.3. In group OJI were cases with Class II division 1 malocclusions and in Group OJs were cases with a Class 1 or borderline malocclusion. The mean values and distribution of the individual values are shown in Table 6.2. The individual changes are illustrated in Figure 6.1.

At the start of treatment, there was no significant mean difference between the incisor mandibular plane angles of the two groups. Changes in the treatment period were found to be significantly larger in Groups OJI. In Group OJI, the incisors became more proclined relative to the mandibular plane. In Group OJs the incisors became more upright relative to the mandibular plane.

At the end of treatment, the mean difference between the two groups was significant. In group OJI, it was 102.34° whereas in Group OJs it was 89.68° . The standard deviation in Group OJI was 8.08° and the range was from 93° to 114° . In Group OJs the standard deviation was 6.67° and the range from 80° to 99° . The mean difference of the changes in the post treatment period was not significant.

At the final examination the mean of Group OJI was 98.11° , and 88.67° of

Table 6.3. Correlation coefficients calculated between the incisal axial inclinations and overbite and overjet.

Significance levels: $n=30$, $r \geq 0.368$, $P < 0.05$; $r \geq 0.464$, $P < 0.01$.

Variable	Variable	n	r	Sign
ILi.MP 2–1	overjet 2–1	30	–0.559	$P < 0.01$
	overbite 2–1	30	–0.308	NS
ILi.MP 3–2	overjet 3–2	30	–0.695	$P < 0.01$
	overbite 3–2	30	–0.424	$P < 0.05$
ILi.MP 3	overjet 3	30	0.212	NS
	overbite 3	30	–0.022	NS
ILs.SN 2–1	overjet 2–1	30	0.629	$P < 0.01$
	overbite 2–1	30	0.307	NS
ILs.SN 3–2	overjet 3–2	30	–0.140	NS
	overbite 3–2	30	0.112	NS
ILs.SN 3	overjet 3	30	–0.007	NS
	overbite 3	30	–0.185	NS
ILs.ILi 2–1	overjet 2–1	30	0.035	NS
	overbite 2–1	30	0.002	NS
ILs.ILi 3–2	overjet 3–2	30	0.444	$P < 0.05$
	overbite 3–2	30	0.493	$P < 0.01$
ILs.ILi 3	overjet 3	30	–0.344	NS
	overbite 3	30	0.099	NS
ILs.ILi 2	overbite 3–2	30	0.118	NS
	overbite 3	30	0.113	NS
	overjet 3–2	30	0.526	$P < 0.01$
	overjet 3	30	0.520	$P < 0.01$

Group OJs. The mean difference between the two groups was significant. It is thus apparent, that in the group of Class II division 1 cases, the incisors were proclined relative to the mandibular plane at the final examination. This in comparison to the group of Class I cases where the incisors were on average almost perpendicular to the mandibular plane. The net changes were significantly different. In Group OJl, the mean incisor mandibular plane angle apparently increased while in Group OJs it decreased between initial and final examination.

In Figure 6.1. the individual values at each examination for the two groups are illustrated. It can be seen that in Group OJl several cases showed considerable increases in incisor mandibular plane angle during treatment followed by post treatment decreases. In Group OJs, the changes were small during the treatment and

Figure 6.2. Scatter diagram illustrating the relationship of the posttreatment changes in overjet and incisor mandibular plane angle. Points illustrating cases from Group OJI are shown by ▲ and points illustrating cases from Group OJs by ■.

posttreatment periods and a tendency for the incisors to become more upright relative to the mandibular plane was discernable.

6.3.1.1. Relationship to overbite and overjet

Table 6.3 shows the calculated correlation coefficients between the incisor mandibular plane angle and the overbite and overjet.

Overjet. The correlation coefficient, between changes in overjet and incisor mandibular plane angle during the treatment period was significant. It indicates a tendency for a proclination of the lower incisors to occur with a decrease in overjet, when evaluated with the mean values and the standard deviations.

The correlation coefficient between the posttreatment changes of overjet and incisor mandibular plane angle was also significant. The scatter diagram (Figure 6.2) illustrates the relationship between the individual changes. It appears that a large increase in overjet in the posttreatment period is associated with a retroclination of

the lower incisors. In individuals where the changes in overjet are small, no specific trend is apparent. From the examination of the groups of large and small overjets, it appears that the large posttreatment changes were found within Group OJ1, the group of the ten largest overjets.

Finally, no relation could be shown between the final overjet and incisor mandibular plane angle.

Overbite. The correlation coefficient between the changes during treatment of overbite and incisor mandibular plane angle was not significant.

The correlation coefficient between changes in the posttreatment period of overbite and incisor mandibular plane angle was significant. When evaluated with the mean values and standard deviations, it indicates a tendency for an increase in overbite to be associated with a retroclination of mandibular incisors.

No relationship was evident between overbite and incisor mandibular plane angle at the final examination.

6.3.2. Maxillary incisal inclination

The mean values and distribution of individual values are shown in Table 6.1.

At the start of treatment, the mean angulation of the maxillary incisor relative to the SN plane was 106.54° , with a standard deviation of 7.74° . The range was from 82° to 118° . The most proclined incisor was in a Class II division 1 malocclusion whereas the most retroclined incisor was in a Class I malocclusion. During the treatment period, a significant mean decrease of 10.67° occurred, with a standard deviation of 9.16° and a range of -31° to 6° .

At the end of treatment, the mean was 95.86° with a standard deviation of 7.56° and a range of 74° to 109° . In the posttreatment period the maxillary incisors became on average more proclined. A significant mean increase of 3.57° with a standard deviation of 4.53° was found. The range was from -3° to 20° . The mean change between initial and final examinations was significant. A mean decrease of 7.10° with a standard deviation of 7.09° and a range of -23° to 7° was found.

To determine the relationship of treatment to posttreatment changes the correlation coefficient ($r=-0.633$, $P<0.01$) was calculated and found to be significant. Although the strong inverse relationship between the changes indicates a relapse tendency, the posttreatment changes are obviously considerably smaller than the treatment changes.

To investigate the differences between Class I and Class II division 1 cases the sample was subdivided into two groups as previously indicated. The values of the measurements are shown in Table 6.2. and illustrated in figure 6.3.

Figure 6.3. Changes during the treatment and posttreatment periods of the maxillary inclination measured relative to the SN plane. Group OJI (large initial overjets) and Group OJs (small initial overjets).

At the start of treatment the incisors in Group OJI (Class II division 1 malocclusions) were found to be significantly more proclined than in Group OJs (Class I cases). Considerable changes occurred in the two groups during the treatment period.

At the end of treatment the mean difference was not significant, indicating similar maxillary incisor inclinations in both groups. There was no significant mean difference of the maxillary incisor inclinations in the post treatment period.

The mean difference between the two groups at the final examination was not significant. The mean difference in the net changes between the two groups was significant. This indicate that in Group OJI a larger decrease of the angle of the maxillary incisors relative to the SN plane occurred.

6.3.2.1. Relationship to overbite and overjet

Table 6.3 shows the correlation coefficients calculated between the inclination of the maxillary incisors relative to the SN plane and the overbite and overjet.

The only correlation between these parameters found to be significant was the relationship between the treatment changes in maxillary inclination and the overjet. When analysed, with the treatment changes, the correlation indicates a tendency for

the angle of the maxillary incisors relative to the SN plane, to decrease as overjet decreases. The incisors tend to become more upright relative to the SN plane in those cases in which a large reduction of overjet occurred. No relationship was evident between the change in inclination of maxillary incisors following treatment and the changes in overbite and overjet. Similarly, no relationship was found at the posttreatment examination.

6.3.3. Interincisal angle

The mean values and distribution of individual values are given in Table 6.1.

At the start of treatment the mean interincisal angle was 121.76° with a standard deviation of 10.88° . The range was from a small interincisal angle of 104° to a large interincisal angle of 155° where the incisors are almost upright relative to each other. During treatment the mean interincisal angle increased significantly by 10.93° standard deviation 12.21° . At the end of treatment the mean interincisal angle was 132.69° and the standard deviation was 9.92° . There was no significant mean change in the post treatment period although it is evident from the standard deviation (6.49°) and the range (-18° to 14°) that individual changes were considerable. At the final examination the mean interincisal angle was 132.86° , the standard deviation was 9.14° and the range was from 116° to 149° .

The correlation coefficient between changes in the treatment and posttreatment periods was found to be significant ($r=-0.621$, $P<0.01$). It denotes a tendency for treatment changes to become reversed in the posttreatment period. However, it should be noted that posttreatment changes are considerably less than the treatment changes.

To investigate the difference between the Class I and Class II division 1 malocclusions the sample was subdivided into two groups as previously indicated (Table 6.2).

No significant mean difference was found between the two groups except at the final examination. The group which was originally Class II division 1, Group OJI, showed an interincisal angle which was less obtuse than the Class I group. The mean differences in the treatment and posttreatment changes were not found to be significant, indicating that the response to treatment is generally similar. However, it appears from the distribution of the individual values that varied responses occurred in both groups.

6.3.3.1. Relationship to overbite and overjet

To determine the relationship of the interincisal angle to overbite and overjet, the correlation coefficients shown in Table 6.3 were calculated.

An analysis of the correlation coefficients revealed no significant relationship between the changes during treatment of the interincisal angle and overjet and overbite.

In the posttreatment period, changes in interincisal angle were correlated with overjet. When evaluated with the mean values and standard deviations this indicates that an increase in the interincisal angle tends to be associated with an increase in overjet. A decrease in interincisal angle tends to be associated with a smaller overjet increase. Similarly, the relationship with overbite was significant. An increase in the interincisal angle is associated with an increase in overbite.

At the final examination, there was no significant correlation coefficient between the interincisal angle and overbite and overjet.

Finally, to examine the relationship of the interincisal angle at the end of treatment to the posttreatment changes in overbite and overjet, as well as to the values of overbite and overjet at the final examination, the correlation coefficients were calculated.

No significant correlation coefficient was found between the interincisal angle at the end of treatment and the posttreatment changes in overbite, or between the interincisal angle and the posttreatment overbite.

A significant correlation was found between the end of treatment interincisal angle and the posttreatment change in overjet. Further, the correlation between the interincisal angle and the final overjet was found to be significant.

6.4. Discussion

Mandibular incisor inclination. In reporting the results of changes of the incisor mandibular plane angle, it has been assumed that the changes were due to the change in inclination of the mandibular incisors. The changes in the inclination of the mandibular incisors are relative and may, to a lesser extent, be due to changes occurring in the mandibular plane. Moreover, it is assumed that the movements which occur are largely of a tipping nature and that it is mainly the position of the incisal edge which is altered relative to the mandibular plane.

From an analysis of the results, it would appear that generally the incisor mandibular plane angle at the posttreatment examination is similar to the inclination at the start of treatment. It therefore appears inadvisable to alter this inclination by treatment due to the possibility of relapse following treatment.

The evaluation of the differences between Class I and Class II cases revealed that the incisal inclination was subject to greater changes in the Class II division 1 cases during the treatment period. Excessive changes occurred in Class II division 1 cases in which proclination of incisors was observed during treatment and a relapse followed treatment. Furthermore, at the final examination, the mandibular incisors

of the initial Class II division 1 cases were generally more proclined than the initial Class I cases.

It follows that if overjet is corrected only by changes in position of maxillary and mandibular incisors, the inherent limitations imposed by the lower incisors require that the upper incisors be retruded to reduce the overjet. The inclination of the lower incisors relative to the mandibular plane should be maintained in a stable position.

There are, however, situations in which the inclination of the mandibular incisors may be changed without significant relapse in the posttreatment period: in Class II division 1 malocclusions, retroclined mandibular incisors were proclined during the treatment period and their position remained relatively stable in the posttreatment period. In Class I malocclusions, generally, the mandibular incisors can be retroclined during treatment and the positions remain stable in the posttreatment period. These findings are further substantiated by the mean difference between the Class I and Class II division 1 malocclusions at the final examination. At this examination it was found that the mandibular incisors in Class II division 1 malocclusions were more proclined than in Class I malocclusions. The differing results for mandibular incisor inclination at the final examination were probably due to differences in facial morphology. Since Björk (1947, 1972) has shown that mandibular incisal inclination varies according to individual facial morphology.

Mills (1966) studied 56 patients in which mandibular incisors had been deliberately proclined during the treatment of various types of malocclusion. A general tendency for relapse was found in the posttreatment period. Exceptions were Class II division 1 cases in which incisors were retroclined at the start of treatment. These findings would appear to be similar to those of the present investigation.

In a similar study of cases, in which incisors had been deliberately retroclined following extraction of first premolars, Mills (1967) found that in the posttreatment period a relapse generally occurred. The most stable results occurred when, mandibular growth was more forward relative to maxillary growth. This group of patients was probably similar to the group of Class I patients examined in the investigation, as they also showed a stable mandibular incisor position.

The relationship in the posttreatment period between changes of incisor position and changes of overbite and overjet were significant. A relapse of proclined mandibular incisors was associated with a relapse of overjet and it is likely that relapse of proclined mandibular incisors results in an overjet relapse. The relationship between incisor changes and overbite changes was also significant in the posttreatment period. However, a causal relationship is not directly apparent. It is likely that relapse of proclined incisors is merely one of many factors that ultimately lead to a deepening of the overbite.

Simons and Joondeph (1973) found that a proclination of mandibular incisors during treatment was significantly correlated with overbite relapse. They recommended that this treatment procedure be avoided in order to enhance stability of deep overbite correction. The present investigation confirms their findings.

Maxillary incisor inclination. The results show that generally in the treatment period the maxillary incisors became more upright (retroclined) relative to the SN plane. Furthermore, the upright positioning appears more marked for Class II division 1, than Class I cases.

In the posttreatment period the mean inclination increased significantly, indicating a proclination. Furthermore, the mean difference between the Class I and Class II division 1 cases was not significant. In the Class I cases both individual increases or decreases were found while in the Class II division 1 cases no decreases in maxillary incisal inclination were found and inclination remained the same or increased.

Kesling et al. (1971) advocated a maxillary incisor inclination relative to the SN plane of 106° or more, at the end of treatment. They found a retroclination in the posttreatment period and a final inclination of 103° which they consider to be the correct inclination. In contrast, Williams (1965) and ourselves found a slight proclination in the same period. As all patients were treated using the Begg technique, these differences may possibly be due to the different retention appliances used.

Finally, the posttreatment changes in maxillary incisor inclination relative to the SN plane were not found to be related to changes in overbite or overjet in the posttreatment period. Therefore the posttreatment increases in maxillary incisor proclination do not appear related to a relapse of overbite or overjet.

Interincisal angle. At the final examination a significant difference was observed between the interincisal angles of Class I and Class II division 1 cases. The interincisal angle is influenced by positional changes of both mandibular and maxillary incisors. The mean difference at the final examination between Class I and Class II division 1 cases was significant for the mandibular incisal inclination but not significant for maxillary incisal inclination. Therefore, it is likely that the differences in the interincisal angle in the present investigation were due to the position of the mandibular incisors. The relationship of the interincisal angle to overjet and overbite was found to be significant in the posttreatment period, but, no significant relationships were evident at the final examination.

There are conflicting reports in the literature on the relationship between changes of interincisal angle and overbite in the posttreatment period:

Riedel (1969) and Schudy (1973) consider the interincisal angle an important

factor in the stability of overbite. Riedel (1969) states that if maxillary and mandibular incisors are tipped into a too upright relationship to one another a deep overbite may result. Schudy (1973) maintains that maxillary and mandibular incisors correctly inclined (interincisal angle approximately 135°) prevent extrusion of each other. Simons and Joondeph (1973), however, found no relationship between posttreatment changes of the interincisal angle and overbite. Our findings confirm a relationship of interincisal angle and overbite changes in the posttreatment period, but, no relationship was found at the final examination.

To conclude: changes during the treatment period of the incisor mandibular plane angle tend to relapse in the posttreatment period. Exceptions were found in Class II division 1 cases in which retroclined incisors at the initial examination were proclined in the treatment period, and in Class I cases in which proclined incisors at the initial examination were retroclined in the treatment period. In such cases the position of the incisors remained stable in the posttreatment period. The treatment objectives should therefore be individualised, taking into account that the incisor mandibular plane angle following treatment differs according to the nature of the original malocclusion. Finally, proclined incisors which relapsed were associated with a relapse of overbite and overjet.

Maxillary incisors tend to become less proclined in the treatment period and slightly more proclined in the posttreatment period. The mean difference in maxillary incisor inclination between Class I and Class II division 1 cases was not significant at the end of treatment or in the posttreatment period although the net change was. Changes of maxillary incisor inclination in the posttreatment period were not shown to be related to changes in overbite or overjet.

Changes of interincisal angle in the posttreatment period were found to be related to relapse of overbite and overjet. It is noteworthy that the changes of the mandibular component of the interincisal angle were associated with relapse of overbite and overjet, while changes of maxillary incisal inclination were not. It thus appears that it is the mandibular incisor component that is of importance and not the interincisal angle as such.

intercanine width and anterior dental arch circumference

7.1. Introduction

The treatment of crowding and abnormal inclination of the six anterior mandibular teeth forms an integral part of orthodontic therapy. Yet this aspect of treatment is often unstable in the posttreatment period. Crowding may be treated symptomatically by the reduction of tooth material (enamel stripping or extraction at the site of crowding) or by increasing the length of the anterior dental arch circumference until sufficient space is available to align all the teeth. Treatment of abnormal inclination of anterior teeth as a group usually occurs by extraction of premolars in cases of proclination, or by lengthening sagittally the arch circumference in cases of retroclination. An increase in the length of the arch circumference may also occur by a transverse expansion. However, this has frequently been reported as unstable.

In the sample investigated the first premolars were extracted for several reasons, of which the following are mentioned:

1. To increase the length of the anterior arch circumference into the space occupied by the premolars to obtain sufficient space to align the six anterior teeth;
2. To avoid transverse or anterior expansion of the dental arch in the treatment of crowding or abnormal proclination.
3. To reduce transverse expansion or anterior displacement of the dental arch as a whole. Such anterior displacement of the dental arch may be due to mesial drift of the buccal teeth resulting from the forces generated by the orthodontic appliance, causing loss of anchorage.

The purpose of this section of the investigation was to study the changes of intercanine width and arch circumference, their interrelationship and their relationship to other variables.

Figure 7.1 Computer plot of a parabolic curve constructed to approach the mesial and distal contact points of the six anterior teeth as closely as possible. Dots * indicate the mesial or distal contact points. The diagram illustrates the average circumference of the anterior mandibular dental arch at the initial examination.

7.2. Measurements

The measurements were made on dental casts. The procedures are described in Chapter 2.2. Figure 2.1 illustrates the landmarks used. Figure 7.1 illustrates the method of measuring the anterior dental arch circumference.

ICW Intercanine width was defined as the distance between the cusps (points 02 and 13) of the canines.

Circum Anterior dental arch circumference was defined as the length of a parabolic curve ($y=ax^2+bx+c$) constructed to approach as closely as possible (a least square fit) the mesial and distal contact points of the canines and incisors (points 01, 03 to 12 and 14). The length of the curve (Figure 7.1) was measured from the distal points of the canines (points 01, 14) projected along the x-axis to intersect the parabolic curve using the formula:

$$S_1 = \int \sqrt{1 + \left(\frac{dy}{dx}\right)^2} dx$$

The measurements were made in the maxillary dental arch (U) and in the mandibular dental arch (L). Measurements were made of 30 cases. In the subsequent text, anterior dental arch circumference may be referred to as circumference.

The circumference changes, are synonymous with crowding changes, as crowding may be calculated by subtracting the length of the circumference from the sum of the mesiodistal widths of the six anterior teeth. The tooth dimensions were taken to be constant and therefore changes in crowding and circumference were considered as synonymous in the present investigation. This means that a decrease in circumference is equal to an increase in crowding.

Table 7.1 Mean changes and distribution of individual changes of intercanine width and anterior dental arch circumference.

Significance levels: $n=30$, $t \geq 2.045$, $P < 0.05$; $t \geq 2.756$, $P < 0.01$.

Variable	n	Mean	S.D.	Range		t	Sign
ICW U 2-1	30	1.95 mm	2.22	-2.8	6.1	4.815	$P < 0.01$
ICW U 3-2	30	-1.18 mm	1.85	-5.1	2.3	3.497	$P < 0.01$
ICW U 3-1	30	0.77 mm	1.33	-2.6	3.4	3.181	$P < 0.01$
ICW L 2-1	30	1.05 mm	2.14	-4.3	4.2	2.659	$P < 0.05$
ICW L 3-2	30	-1.48 mm	1.36	-4.0	1.6	5.850	$P < 0.01$
ICW L 3-1	30	-0.43 mm	1.54	-4.5	2.8	1.630	NS
Circum U 2-1	30	2.88 mm	3.23	-3.6	8.6	4.896	$P < 0.01$
Circum U 3-2	30	-1.00 mm	1.24	-2.9	1.5	4.405	$P < 0.01$
Circum U 3-1	30	1.88 mm	2.59	-3.6	6.6	3.993	$P < 0.01$
Circum L 2-1	30	2.78 mm	2.01	-0.5	7.7	7.469	$P < 0.01$
Circum L 3-2	30	-1.94 mm	1.24	-4.8	0.5	8.691	$P < 0.01$
Circum L 3-1	30	0.84 mm	1.85	-3.1	5.5	2.501	$P < 0.05$

* U and L indicate maxillary and mandibular arch respectively.

7.3. Results

The results of the statistical analysis will be presented in the following order: firstly the data on mandibular and maxillary intercanine width; followed by the data on mandibular and maxillary anterior dental arch circumference; finally, the interrelation of changes in the posttreatment period of intercanine width, anterior dental arch circumference, overbite, incisor inclinations and the sagittal jaw relationship.

A number of correlations that appear of importance will be more extensively treated by discussing their scatter diagrams to examine individual changes.

7.3.1. Intercanine width

Mean values and distribution of individual values are shown in Table 7.1.

Changes in mandibular intercanine width. In the treatment period a significant mean increase of 1.05 mm in intercanine width, occurred with a standard deviation of 2.14 mm. The range of changes was from an increase of 4.2 mm to a decrease of 4.3 mm. In the posttreatment period a significant mean decrease was found of 1.48 mm, standard deviation 1.36 mm. The largest individual decrease was 4.0 mm and the largest increase was 1.6 mm. The mean change between initial and final exami-

Table 7.2 Correlation coefficients between changes in anterior dental arch circumference, between changes in intercanine width, and their interrelationship.
Significance levels: $n=30$, $r \geq 0.362$, $P \leq 0.05$; $r \geq 0.464$, $P < 0.01$.

Variable	Variable	n	r	Sign
Circum L 2-1	Circum L 3-2	30	-0.464	$P < 0.01$
	Circum L 3-1	30	0.805	$P < 0.01$
Circum L 3-2	Circum L 3-1	30	0.151	N.S.
Circum U 2-1	Circum U 3-2	30	-0.802	$P < 0.01$
	Circum U 3-1	30	0.556	$P < 0.01$
Circum U 3-2	Circum U 3-1	30	0.050	N.S.
Circum U 3-2	ICW U 3-2	30	0.724	$P < 0.01$
	ICW L 3-2	30	0.684	$P < 0.01$
	Circum L 3-2	30	0.600	$P < 0.01$
Circum L 3-2	ICW L 3-2	30	0.516	$P < 0.01$
	ICW U 3-2	30	0.686	$P < 0.01$
ICW L 2-1	ICW L 3-2	30	-0.708	$P < 0.01$
	ICW L 3-1	30	0.771	$P < 0.01$
ICW L 3-2	Circum L 3-1	30	-0.095	N.S.
ICW U 2-1	ICW U 3-2	30	-0.802	$P < 0.01$
	ICW U 3-1	30	0.556	$P < 0.01$
ICW U 3-2	ICW U 3-1	30	0.050	N.S.

* U and L indicate the maxillary and the mandibular dental arch respectively.

nations was not significant. However, the standard deviation of 1.54 mm and the range of -4.5 to 2.8 mm indicate considerable individual variation.

Changes in maxillary intercanine width. In the treatment period a significant mean increase in intercanine width of 1.95 mm, standard deviation 2.22 mm took place. The range of changes was from a decrease of 2.8 mm to an increase of 6.1 mm. In the posttreatment period, a significant mean decrease of 1.18 mm was found. The standard deviation was 1.85 mm and the range of changes was from a decrease of 5.1 mm to an increase of 2.3 mm. The mean change between the initial and final examination was significant. A mean increase in intercanine width of 0.77 mm, standard deviation 1.33 mm and range of -2.6 mm to 3.4 mm was found.

Correlations of mandibular intercanine width. To examine the interrelationships of the changes in mandibular intercanine width a number of correlations were calculated (Table 7.2).

The correlation coefficient between the changes in mandibular intercanine width during the treatment and posttreatment periods was found to be significant.

Figure 7.2. The scatter diagram illustrates the distribution of points denoting treatment and posttreatment changes in intercanine width in the mandibular dental arch.

The correlation when evaluated with the mean values and their standard deviations indicates a tendency for an increase, or respectively a decrease in intercanine width during treatment to be associated with a decrease, or respectively an increase in intercanine width following treatment. A tendency to return to the original width is obvious. The scatter diagram (Figure 7.2) illustrates the distribution of the individual values. For descriptive purposes the scatter diagram was divided into four quadrants.

- Quadrant 1. No points were distributed in quadrant 1. This means that in no instance was an increase in intercanine width found both during and following treatment.
- Quadrant 2. One point was found in quadrant 2. A decrease in the intercanine width occurred during treatment followed by an increase in the posttreatment period. In this case the mandibular canines were buccally positioned.
- Quadrant 3. Five points. A decrease occurred in the intercanine width during treatment followed by a further posttreatment decrease.
- Quadrant 4. Twenty-two points. In these cases an increase during the treatment period was followed by a decrease in the posttreatment period. Eleven cases represented by the points which lie above the z-axis had treatment changes which were greater than posttreatment changes i.e. there was an in-

crease in the intercanine width between initial and final examinations. The eleven points which lie below the z-axis represent cases with posttreatment changes which were greater than treatment changes i.e. There was a decrease in the intercanine width between initial and final examination.

Two points were distributed on the y-axis. No change occurred during treatment but a decrease was found in the posttreatment period.

The correlation coefficient relating changes in the mandibular intercanine width during the treatment period to the changes between the initial and final examination was found to be significant. It indicates when evaluated with the respective means and standard deviations that an increase, or respectively a decrease in intercanine width during treatment tends to result in a net increase, or respectively a net decrease.

No relationship between the changes which occur following treatment and the changes between the initial and final examination could be shown.

Correlations of maxillary intercanine width. The correlation coefficients between changes in maxillary intercanine width, are given in Table 7.2.

The correlation coefficient between changes of maxillary intercanine width in the treatment and the posttreatment periods was significant. It indicates when analysed with the means and standard deviations, that an increase in intercanine width in the treatment period is associated with a decrease in the posttreatment period. Similarly, a decrease in the treatment period is associated with an increase in the posttreatment period. A tendency to return to the original width is obvious.

The correlation coefficient between the changes in maxillary intercanine width during the treatment period and the changes between the initial and final examination was significant. The correlation coefficient when evaluated with the means and standard deviations, indicates that a large, respectively small increase during treatment is associated with a large, respectively small increase between initial and final examinations.

The correlation coefficient between changes in the posttreatment period and the changes between initial and final examinations was not significant.

7.3.2. Anterior dental arch circumference

Table 7.1 shows the mean values and distribution of individual values.

Changes in mandibular anterior dental arch circumference. During the treatment period, the mean length of the circumference increased significantly by 2.78 mm, standard deviation 2.01 mm. The largest individual increase of circumference was 7.7 mm and the smallest decrease 0.5 mm. In the posttreatment period a significant mean decrease was found of 1.94 mm, standard deviation 1.24. The largest decrease

Figure 7.3. The scatter diagram illustrates the distribution of points denoting individual treatment and posttreatment changes of the mandibular anterior dental arch circumference.

was 4.8 mm and the largest increase was 0.5 mm. Finally it was found that a significant mean increase in the length of the circumference occurred between initial and final examinations. The mean increase was 0.84 mm, standard deviation 1.85 mm and the range was from -3.1 mm to 5.5 mm.

Changes in maxillary anterior dental arch circumference. In the treatment period, the mean circumference of the maxillary dental arch increased significantly. The mean value was 2.88 mm, standard deviation 3.23. The range was from a decrease of -3.6 mm to an increase of 8.6 mm. In the posttreatment period, a significant mean decrease was found. The mean decrease was 1.00 mm, standard deviation 1.24 mm and range was from a decrease of 2.9 mm, to an increase of 1.5 mm. Finally, a significant mean increase in circumference between initial and final examinations was observed. A mean increase of 1.88 mm was found, standard deviation 2.59, and a range from -3.6 mm to 6.6 mm.

Correlations of mandibular anterior dental arch circumference. The correlation coefficients are shown in Table 7.2. The correlation coefficient between changes of

circumference in the treatment period and posttreatment periods was found to be significant. It indicates when evaluated with the mean changes and their standard deviations that there was a tendency for an increase in the circumference during treatment to be associated with a decrease in the circumference after treatment. A tendency to return to the original circumference is obvious. The scatter diagram (Figure 7.3) illustrates the distribution of the individual points.

- Quadrant 1. In no instance was an increase in the length of the circumference during treatment followed by an increase after treatment.
- Quadrant 2. One point. In one case an increase in arch circumference during treatment was followed by a slight increase after treatment.
- Quadrant 3. One point. A decrease occurred during treatment followed by a further decrease.
- Quadrant 4. 27 points. In 27 cases an increase in the circumference occurred during treatment and a subsequent decrease after treatment. The ten points below the z-axis represent cases in which the posttreatment decrease was greater than the treatment increase, i.e. in these cases the circumference decreased in length between the initial and final examinations. In the remaining 17 cases the circumference increased between the initial and final examination.

The correlation coefficient, between changes of circumference in the treatment period and the changes between the initial and final examination was significant. It indicates when evaluated with the respective mean and standard deviations that a large increase during treatment of the circumference is associated with a net increase between initial and final examinations. Again, the tendency to return to the original dimension is obvious.

The correlation coefficient, between changes in the posttreatment period and the changes between the initial and final examinations was not significant.

Correlations of maxillary anterior dental arch circumference. The correlation coefficient between treatment and posttreatment changes of the circumference was significant. It indicates when considered with the mean values and standard deviations that an increase, respectively a decrease during treatment in the circumference, is associated with an increase, respectively a decrease in the posttreatment period.

The correlation coefficient between treatment changes and the changes occurring between initial and final examinations was significant. It indicates when evaluated with the mean values and standard deviations that an increase, respectively a decrease in the treatment period, is related to an increase, respectively a decrease between the initial and final examination.

Finally, the correlation coefficient between the changes in the posttreatment period and the changes between the initial and final examination was not found significant.

Table 7.3. Correlation coefficients relating posttreatment dental arch changes of intercanine width and anterior dental arch circumference to overjet, overbite the inclinations of incisors and sagittal jaw changes.
Significance level: $n=30$, $r \geq 0.362$, $P \leq 0.05$.

Variable	overjet 3-2	overbite 3-2	ILS.SN 3-2	ILi.MP 3-2	A.N.B.* 3-2	S.N.Pg* 3-2
Circum U 3–2	0.125	–0.065	0.192	0.239	0.068	–0.333
Circum L 3–2	–0.243	–0.312	–0.039	0.441	0.129	0.215
ICW U 3–2	0.008	–0.138	–0.237	0.277	–0.116	0.250
ICW L 3–2	0.030	0.174	0.017	0.045	0.240	0.259

* A.N.B. and S.N.Pg are referred to in chapter 10.
U and L indicate maxillary and mandibular dental arches respectively.

7.3.3. Correlations

Relationship between intercanine width and anterior dental arch circumference.
The relationships of posttreatment changes in intercanine width and circumference in maxillary and mandibular dental arches were investigated (Table 7.2). All four parameters were found to be significantly correlated. These correlation coefficients when evaluated with their respective mean values and standard deviations denote that decreases, respectively increases of arch dimension tend to be associated with decreases, respectively increases of the other arch dimensions.
An association could not be shown between changes in the posttreatment period and its duration.

In addition to the interrelationship of the changes in the dental arches, the correlation coefficients were examined of the changes in intercanine width and dental arch circumference in the posttreatment period and the changes of overbite, overjet, the sagittal inclination of maxillary and mandibular incisors and changes in sagittal jaw relationship (Table 7.3). With one exception, the correlation coefficients were not found significant. The correlation coefficient between changes in the posttreatment period of the mandibular arch circumference and the incisor mandibular plane angle was significant. The correlation coefficient indicates when considered with the means and standard deviations, that a retroclination of the mandibular incisor is related to a decrease in circumference.

7.3.4. Extraction diastema

An inspection of the dental casts of the final examination was made to count the number of extraction diastemata and to examine the relationship of the presence or

Table 7.4 The table illustrates the number of dental casts with or without extraction diastemata and the relationship to crowding.

Variable	Mandible		Maxilla	
	crowding	no crowding	crowding	no crowding
Extraction diastema present	6	2	4	9
Extraction diastema absent	16	6	10	7

absence of extraction diastemata to crowding in the anterior dental arch. The findings are shown in Table 7.4.

Mandibular dental arch. In the mandibular arch, extraction diastemata were found in eight cases. In two cases the diastemata were bilateral and in six unilateral. In 22 cases crowding was present: in six of these cases in association with a diastema and in 16 cases there was no diastema present. In eight cases there was no crowding: in two of these cases extraction diastemata were present and in six cases there was no diastema. There appears to be no association between the presence or absence of a diastema and crowding.

Maxillary dental arch. In the maxillary arch, extraction diastemata were found in 13 cases. In nine cases the diastemata were bilateral and in four cases unilateral. Crowding was present in 14 cases: in four of these cases extraction diastemata were present and in ten cases they were absent. In 16 cases there was no crowding: in seven cases there was no extraction diastema and in nine cases they were present. There is no obvious relationship between the presence or absence of a diastema and crowding.

7.4. Discussion

The intercanine width. The mandibular intercanine width decreased in the post-treatment period irrespective of whether an increase or decrease occurred in the treatment period. In only one instance was a posttreatment increase in intercanine width observed. In this case a decrease in intercanine width occurred during treatment. Further, the relationship between changes in the treatment and post-treatment period was significant, indicating a relapse tendency. The mean change in mandibular intercanine width between the initial and final examination was not found to be significant. However, it is of note that in individual cases, an increase or decrease in mandibular intercanine width occurred. No directly obvious explanation could be found for such different responses.

The mean maxillary intercanine width tended to decrease in the posttreatment

period. However, the mean decrease was less than the treatment increase and a resultant net mean increase in width occurred. This in contrast to the intercanine width of the mandibular arch which was not found to increase significantly in the total period of the examination. In individual cases either increases or decreases were observed. Furthermore the relationship between changes in the treatment and posttreatment periods was significant and indicated a relapse tendency.

Anterior dental arch circumference. In both maxillary and mandibular arches mean increases in the treatment period were followed by a mean decrease in the posttreatment period. However, the changes in the posttreatment period were smaller and mean net increases in arch circumference occurred. Furthermore, the relationship between changes in the treatment and posttreatment periods was significant indicating a tendency for an increase in arch circumference to be followed by a decrease. An important observation of the individual changes between initial and final examination is that in some instances large increases in circumference took place denoting substantial decrease of crowding. Yet, in other cases the crowding appears to have increased.

As explained previously (Chapter 7.2.) the changes in circumference are synonymous with changes in crowding, when crowding is calculated by subtracting the circumference length from the mesiodistal width of the six anterior teeth. This means that an increase in the circumference length results in the same decrease in crowding. The discussion is therefore applicable to both variables. It is evident from the findings that the mandibular arch circumference generally increased during treatment and subsequently decreased in the posttreatment period. Unlike the intercanine width of the mandibular dental arch, where the mean change between initial and final examination was not found to be significant, the mean circumference was found to be significantly increased. This means that crowding in the anterior dental arch decreased between the initial and final examinations. It may therefore be concluded that at the time of the final examination the average crowding was less than at the start of treatment. A similar finding is applicable to the crowding in the maxillary dental arch.

The finding that changes of the mandibular intercanine width in the posttreatment period, were related to changes of mandibular arch circumference is in itself not evidence of a cause and effect relationship. Rather it appears likely that the factors which cause a decrease in intercanine width in the posttreatment period, are the same factors responsible for a decrease in the arch circumference. The relationship of intercanine width to arch circumference being due to their close physical relationship. A similar argument is applicable to the maxillary intercanine width and circumference. A factor which was found to be related to posttreatment changes of the anterior circumference of the mandibular dental arch was a change

in inclination of the mandibular incisors: a retroclination of incisors proclined during treatment resulted in a decrease in circumference. No other factors could be found which were likely to cause a decrease in circumference.

There were few extraction diastemata present in the mandibular arch at the final examination and there is no indication that crowding is less when extraction diastemata are present. There were a larger number in the maxillary arch but there was also no indication that crowding was less when these diastemata were present.

Earlier studies on arch width by Walter (1953,1962) and Arnold (1963), indicate that in treatment with the Edgewise technique, arch width, increased during treatment, tends to decrease after the end of treatment. Riedel (1969), reviewed the literature on studies of relapse in orthodontically treated malocclusions. Riedel states: "In almost every instance mandibular intercanine width tended to return to or maintain the original dimensions after all retaining appliances had been removed for several years". The findings of the present investigation generally confirm this statement.

Diverse factors have been suggested by various investigators to explain the relapse of crowding.

Nance (1947) studied extensively the results of extraction and non-extraction treatment. He found that when expansion in sagittal or transverse direction occurred during treatment the result was unstable. Nance concluded that it was necessary to extract teeth to obtain a correct inclination of the incisors. He felt that this would produce a stable result. Begg (1965) and Graber (1966), however, hold contradictory views.

Begg (1965) also advocates tooth extraction to correct crowding and rotations but recognises that notwithstanding the extraction of first premolars and the distal movement of the canines some form of relapse occurs. Begg found that relapse is caused by a lack of interproximal attrition and the tendency of teeth to migrate mesially.

Graber (1966) makes the point that irrespective of whether or not teeth are extracted, crowding tends to occur after treatment. Graber proposes two explanations for the relapse tendency:

1. the predominance of the morphogenetic pattern overriding the treatment results;
2. an imbalance in muscular pressures in Class I cases treated by dental arch expansion.

In addition to the above, it is of note that Björk (1969,1972) found that crowding in the mandibular dental arch is associated with extreme forms of mandibular rotation in non treated subjects. Moreover, longitudinal studies (Sillman 1964, and Knott 1972) and cross sectional studies (Lovell and Foster 1969) of non treated subjects indicate that little or no significant change can be expected in intercanine width after the eruption of the permanent canines or 12 years of age.

With current methods of treatment, premolars are frequently extracted to treat crowding and rotations of incisors and canines. In the present study, it has been found that, in both mandible and maxilla in the posttreatment period the mean anterior dental arch circumference tends to decrease and hence crowding increases despite the extraction of four first premolars. However, a slight mean increase in circumference, and hence a slight decrease in crowding occurred between initial and final examinations. Moreover in some cases a net increase in circumference was observed while in others a net decrease occurred. It is clear that not every case follows the mean pattern and hence the decision to extract teeth cannot be based on generalised findings. A multifactorial complex appears to be related to the problem of crowding. It is suggested that the indication for the extraction of teeth for the treatment of crowding should be reappraised on the basis of further investigation.

direction of condylar growth

8.1. Introduction

Björk (1955, 1963, 1969) recognised that the study of dento-facial changes using lateral cephalometric radiographs, without the use of fixed reference points, was an unreliable method. He, therefore, introduced metallic implants into the jaws of children to serve as such. To study the growth of the mandible, lateral cephalometric radiographs were compared by orientating the radiographs so that implants in the mandible were superimposed. He found that the direction of growth of mandibular condyles was variable. In some instances it took place in a vertical direction and in others, in a sagittal direction. Furthermore, it was found that with vertical condylar growth, resorption at the angle of the mandible occurred, whereas, in sagittal growth, resorption was found to be less or an apposition was observed. Apposition also occurred below the symphysis of the mandible, and was greatest in cases of vertical condylar growth.

Using the implant method Björk and Skieller (1972) investigated the possible relation between direction of condylar growth and changes of the mandibular plane inclination. They found a significant correlation between the direction of condylar growth and overbite, and direction of condylar growth and changes of mandibular plane inclination. No relation could be demonstrated between overbite and mandibular plane inclination.

While using metallic implants to superimpose mandibles, Björk observed that a number of structures in the mandible (Chapter 2.3.7.) were relatively stable during the growth period and that these structures could be used as reference structures. This method is named the structural method of superimposition.

In the present investigation the direction of condylar growth and the change in inclination of the mandibular plane were investigated by means of the structural method. The measurements were made to determine the relationship between

Figure 8.1.. The method used to determine the direction of condylar growth (Ar3-1.RP1). The direction of condylar growth is determined by the angle formed by the line drawn through Ar1 and Ar3, and the mandibular plane of the initial examination (MP1). The solid line represents the mandible at the initial examination and the dotted line the final examination when mandibles are superimposed on natural reference structures. An example of vertical condylar growth.

changes which occur in the shape of the mandible and those of overbite, vertical changes in incisor positions, changes in occlusal plane inclination, changes in dental arch circumference and intercanine width.

8.2 Methods

8.2.1. Measurements

The technical details of the method of superimposition as it was used in the present study are described in Chapter 2.3.7. Definitions of the points, planes and reference structures are given in Chapter 2.3.

The method of measuring the direction of condylar growth and changes in mandibular plane inclination are illustrated in Figure 8.1 and 8.2 respectively.

Ar3-1.RP1 Direction of condylar growth. This was determined from the angle of the line drawn through the points Ar1 and Ar3 and the mandibular plane of the initial examination (MP1), when the tracings of the mandibles of the initial and final examination were superimposed on the reference structures in the mandible.

The point articulare (Ar) was considered to be representative for the position of the condyles.

Figure 8.2. The method used to determine the change in inclination of the mandibular plane (MP3-1.RP1). The change in inclination of the mandibular plane (MP) is determined by the difference between the inclination of MP1 and MP3 measured relative to the ramal plane at the first examination. The solid line represents the mandible at the initial examination and the dotted line the final examination when the mandibles are superimposed on the natural reference structures.

MP3-1.RP1 The change in mandibular plane inclination. This was determined from the difference between the inclination of MP1 and MP3, measured relative to the ramal plane of the initial examination (RP1), when the mandibles were superimposed on the reference structure in the mandible.

The measurements were made on a sample of 21 cases (Chapter 2.3.7). A large Ar3-1. MP1 angle indicates a sagittal direction of condylar growth (SCG). A small Ar3-1. MP1 angle indicates a vertical direction of condylar growth (VCG). Figure 8.6 illustrates a case with a sagittal direction of condylar growth and Figure 8.7 with a vertical direction of condylar growth. A large positive change in mandibular plane inclination indicates a sagittal direction of condylar growth.

According to Björk (1969), the growth direction of the condyle is usually curvilinear. That observation is based on a large number of successive superimpositions. However, in the present study, only three radiographs were studied. It is therefore impossible to demonstrate a curvilinear growth. Also, an anterior positioning of the mandible as a result of the effects of treatment may cause the condyle to be more anteriorly positioned. This influences the determination of articulare which, as it is a derived landmark, does not, however, indicate a change in the structure of the con-

Figure 8.3. Diagram of the analysis procedure of the direction of condylar growth in relation to overbite. The sample of 21 cases was arbitrarily divided on the basis of the direction of condylar growth into two groups: Sagittal direction of condylar growth (Group SCG) and vertical direction of condylar growth (Group VCG). A further subdivision was made on the basis of overbite to form four subgroups: Sagittal direction of condylar growth and large or small overbite (Subgroup SCGI and Subgroup SCGs); vertical direction of condylar growth and large or small overbite (Subgroup SCGI and Subgroup VCGs). The two groups were compared and comparison was made between different subgroups. Mandibular rotation was examined using the same procedure of analysis. The groups and subgroups are the same as the above.

dyle. This possible effect of treatment is likely to diminish by the final examination. For these reasons the intermediate stage (AR2) was not used but only the total change evaluated between initial and final examinations.

8.2.2. Procedure of analysis

The following procedure was used to analyse the direction of condylar growth in relation to overbite and other parameters (Figure 8.3.). The sample was divided, arbitrarily, into two groups on the basis of the direction of condylar growth (CG):

- Group SCG Sagittal direction of condylar growth (n=8).
- Group VCG Vertical direction of condylar growth (n=13).

Table 8.1. Mean values and distribution of individual values of the direction of condylar growth and change in mandibular plane inclination.

Variable	Group	n	Mean	S.D.	Range	
Ar3-1.MP1	CG	21	132.74°	12.44	94	175
Ar3-1.MP1	SCG	8	147.96°	11.35	142	175
Ar3-1.MP1	VCG	13	123.37°	13.01	94	137
MP3-1.RP1	CG	21	1.24°	1.52	-4	4
MP3-1.RP1	SCG	8	-0.68°	1.70	-4	2
MP3-1.RP1	VCG	13	2.69°	1.40	1	4

A further subdivision of the two groups into four subgroups was made on the basis of the initial overbite:

- Subgroup SCGI Sagittal direction of condylar growth, large initial overbite (n=3).
- Subgroup SCGs Sagittal direction of condylar growth, small initial overbite (n=5).
- Subgroup VCGI Vertical direction of condylar growth, large initial overbite (n=5).
- Subgroup VCGs Vertical direction of condylar growth, small initial overbite (n=8).

Comparisons were made between the two groups and between the various subgroups. For the evaluation of the relationship of overbite to the direction of condylar growth, individual values were also examined.

8.3. Results

8.3.1. Direction of condylar growth

The mean values and distribution of individual values are shown in Table 8.1.

The mean direction of condylar growth for the sample was 132.74° with a standard deviation of 12.44° and a range from 94° (vertical direction of condylar growth) to 175° (sagittal direction of condylar growth).

In Group SCG, the mean direction of condylar growth was 147.96° with a standard deviation of 11.35° and a range of 142° to 175°. In Group VCG the mean direction of condylar growth was 123.37° with a standard deviation of 13.01° and a range of 94° to 137°. The mean difference between the two groups was significant ($t=4.399$, $P<0.01$).

8.3.2. Relationship of the direction of condylar growth to overbite.

To determine the difference in overbite between the groups with sagittal and

Table 8.2. Mean values and distribution of individual values of overbite for the two groups with a sagittal direction of condylar growth (Group SCG) and a vertical direction of condylar growth (Group VCG). The significance of the mean differences between the two groups was evaluated using the t-test.
Significance level; $n=21, t \geq 2.080, P < 0.05$.

Variable	Group SCG		Group VCG		t	Sign
	Mean	S.D.	Mean	S.D.		
Overbite 1	3.6 mm	1.6	3.2 mm	1.8	0.531	NS
Overbite 2-1	-2.3 mm	1.8	-1.3 mm	1.6	1.245	NS
Overbite 2	1.3 mm	0.6	1.8 mm	0.8	1.558	NS
Overbite 3-2	1.9 mm	0.8	1.2 mm	1.8	1.146	NS
Overbite 3	3.2 mm	0.6	3.0 mm	1.7	0.234	NS
Overbite 3-1	-0.4 mm	2.0	-0.2 mm	1.0	0.405	NS

vertical directions of condylar growth (Group SCG and Group VCG), the mean values of overbite for the successive stages of the investigation were calculated for each group (Table 8.2.). The t-test was applied to evaluate the significance of the mean difference between the two groups. The results show that at no stage of the examination was the mean difference between the two groups significant.

A further analysis of the relationship of the direction of condylar growth to overbite was carried out by a comparison of the subgroups. The data of individual values in each subgroup are listed in Table 8.3 and the comparison of the various subgroups in Table 8.4.

Large initial overbite. The mean values of overbite of the two subgroups (Subgroup SCGI and VCGI) with a sagittal or vertical direction of condylar growth and a large overbite were compared.

At the initial examination, the mean difference in overbite between the two subgroups was not significant. At the end of treatment the mean overbite was significantly smaller in the subgroup with sagittal direction of condylar growth than in the subgroup with a vertical direction of condylar growth. The mean overbite in the subgroup with sagittal direction of condylar growth was 0.8 mm, with a standard deviation of 0.6 mm, while in the subgroup with vertical condylar growth the mean overbite was 2.4 mm and the standard deviation 0.7 mm.

At the final examination, the mean overbite was again significantly smaller in the subgroup with sagittal direction of condylar growth. This mean value was 2.6 mm with a standard deviation of 0.3 mm while the mean value of the overbite in the subgroup with vertical direction of condylar growth was 4.8 mm with a standard deviation of 1.2 mm.

Table 8.3 Mean values and the individual values of the sample of 21 cases divided into four subgroups according to the direction of condylar growth and the initial overbite. (Direction of condylar growth in degrees, overbite in mm).

Subgroup SCGI Sagittal direction of condylar growth and large initial overbite.

Subgroup SCGs Sagittal direction of condylar growth and small initial overbite.

Subgroup VCGI Sagittal direction of condylar growth and large initial overbite.

Subgroup VCGs Sagittal direction of condylar growth and small initial overbite.

Subgroup SCGI							
Case	Ar3-1.MPI	OB 1	OB 2-1	OB 2	OB 3-2	OB 3	OB 3-1
4251	151	7.1	-5.5	1.5	0.7	2.2	-4.8
4799	143	3.9	-3.6	0.3	2.4	2.7	-1.2
3269	145	4.4	-3.7	0.7	2.3	3.0	-1.5
Mean	145.6	5.1	-4.2	0.8	1.7	2.6	-2.5
S.D.		1.6	1.0	0.6	0.9	0.3	2.0

Subgroup SCGs							
Case	Ar3-1.MPI	OB 1	OB 2-1	OB 2	OB 3-2	OB 3	OB 3-1
3170	142	3.4	-2.0	1.4	2.7	4.1	0.7
4445	142	2.7	-1.3	1.4	1.5	2.9	0.2
3473	141	3.1	-0.6	2.6	0.5	3.1	0.0
3430	145	2.6	-1.5	1.1	2.7	3.8	1.2
3614	175	1.9	-0.2	1.7	1.7	3.5	1.6
Mean	149.0	2.7	-1.0	1.6	1.8	3.4	0.7
S.D.		0.5	0.7	0.5	0.9	0.5	0.6

Subgroup VCGI							
Case	Ar3-1.MPI	OB 1	OB 2-1	OB 2	OB 3-2	OB 3	OB 3-1
4657	137	5.4	-1.8	3.6	1.8	5.3	-0.1
3724	114	4.8	-1.9	2.9	1.5	4.4	-0.4
4246	126	4.6	-2.9	1.8	2.8	4.6	0.0
4243	116	6.1	-4.1	1.9	2.8	6.6	0.5
5211	113	4.9	-2.7	2.2	0.9	3.1	-1.8
Mean	121.2	5.1	-2.6	2.4	2.3	4.8	-0.3
S.D.		0.5	0.9	0.7	1.4	1.2	0.8

Subgroup VCGs							
Case	Ar3-1.MPI	OB 1	OB 2-1	OB 2	OB 3-2	OB 3	OB 3-1
3470	94	3.0	-0.9	2.1	-1.3	0.8	-2.2
4697	138	0.5	1.1	1.6	0.1	1.7	1.2
4923	120	3.1	-1.4	1.7	1.3	3.1	0.0
5076	134	3.7	-2.4	1.3	1.3	1.5	-0.8
5074	119	2.3	-1.7	0.6	0.9	1.5	-0.8
5170	120	0.6	1.0	1.6	-0.9	1.5	0.1
3679	137	0.9	1.6	2.6	-0.5	2.1	1.1
5013	136	1.6	-1.1	0.6	1.7	2.3	0.6
Mean	124.8	1.9	-0.4	1.5	-0.3	1.8	-0.1
S.D.		1.2	1.4	0.6	1.1	0.8	1.1

Table 8.4. Comparison of overbite between the four different subgroups.

Significance levels: $n=8$, $t \geq 2.447$, $P < 0.05$; $t \geq 3.707$, $P < 0.01$. $n=13$, $t \geq 2.201$, $P < 0.05$; $t \geq 3.012$, $P < 0.01$.

	Subgroup SCGI ($n=3$)		Subgroup VCGI ($n=5$)			
Variable	Mean	S.D.	Mean	S.D.	t	Sign
Overbite 1	5.1 mm	1.6	5.1	0.5	0.020	NS
Overbite 2-1	-4.2 mm	1.0	-2.6	0.9	2.260	NS
Overbite 2	0.8 mm	0.6	2.4	0.7	3.126	$P < 0.05$
Overbite 3-2	1.7 mm	0.9	2.3	1.4	0.548	NS
Overbite 3	2.6 mm	0.3	4.8	1.2	2.749	$P < 0.05$
Overbite 3-1	-2.6 mm	2.0	-0.3	0.8	2.155	NS

	Subgroup SCGI ($n=3$)		Subgroup SCGs ($n=5$)			
Variable	Mean	S.D.	Mean	S.D.	t	Sign
Overbite 1	5.1 mm	1.6	2.7	0.5	3.049	$P < 0.05$
Overbite 2-1	-4.2 mm	1.0	-1.0	0.7	5.177	$P < 0.01$
Overbite 2	0.8 mm	0.6	1.6	0.5	1.858	NS
Overbite 3-2	1.7 mm	0.9	1.8	0.9	0.064	NS
Overbite 3	2.6 mm	0.3	3.4	0.5	2.449	$P < 0.05$
Overbite 3-1	-2.6 mm	2.0	0.7	0.6	3.461	$P < 0.05$

	Subgroup VCGI ($n=5$)		Subgroup VCGs ($n=8$)			
Variable	Mean	S.D.	Mean	S.D.	t	Sign
Overbite 1	5.1 mm	0.5	1.9	1.2	5.324	$P < 0.01$
Overbite 2-1	-2.6 mm	0.9	-0.4	1.4	2.937	$P < 0.05$
Overbite 2	2.4 mm	0.7	1.5	0.6	2.343	$P < 0.05$
Overbite 3-2	2.3 mm	1.4	0.3	1.1	2.657	$P < 0.01$
Overbite 3	4.8 mm	1.2	1.8	0.8	4.886	$P < 0.01$
Overbite 3-1	-0.3 mm	0.8	-0.1	1.1	0.402	NS

	Subgroup SCGs ($n=5$)		Subgroup VCGs ($n=8$)			
Variable	Mean	S.D.	Mean	S.D.	t	Sign
Overbite 1	2.7 mm	0.5	1.9	1.2	1.247	NS
Overbite 2-1	-1.0 mm	0.7	-0.4	1.4	0.862	NS
Overbite 2	1.6 mm	0.5	1.5	0.6	0.316	NS
Overbite 3-2	1.8 mm	0.9	0.3	1.1	2.383	$P < 0.05$
Overbite 3	3.4 mm	0.5	1.8	0.8	3.654	$P < 0.01$
Overbite 3-1	0.7 mm	0.6	-0.1	1.1	1.476	NS

The mean changes between the successive examinations were not found to differ significantly for the two groups.

The individual values of overbite are also of interest as, at the end of treatment the smallest value of overbite in the subgroup with a sagittal direction of condylar growth was 0.3 mm and the largest 1.5 mm. In contrast, in the subgroup with vertical direction of condylar growth the smallest overbite was 1.8 mm and the largest 3.6 mm. At the final examination in the subgroup with sagittal condylar growth the smallest overbite was 2.2 mm and the largest 3.0 mm. In the group with the vertical direction of condylar growth the individual overbites were all larger. The smallest overbite was 3.1 mm and the largest 6.6 mm. An example of the treatment of a case with sagittal direction of condylar growth and deep overbite is shown in Figure 8.6. Figure 8.7 shows a case with vertical direction of condylar growth and deep overbite.

Small initial overbite. The mean values of overbite of the two subgroups (Subgroup SCGs and Subgroup VCGs) with sagittal or vertical condylar growth and a small initial overbite were compared (Table 8.4.). At the initial examination the mean difference in overbite between the two subgroups was not significant. Similarly, at the end of treatment the mean difference was not significant. However, at the final examination the mean overbite in the subgroup with sagittal direction of condylar growth was larger than that of the subgroup with vertical direction of condylar growth.

The mean values of the changes during the treatment period were not significantly different for the two subgroups, nor were the net changes. The increase in the post treatment period was found to be significantly larger in the subgroup with sagittal direction of condylar growth.

The tables of individual values (Table 8.3.) show that in the subgroup with sagittal direction of condylar growth, the overbite decreased in all cases during the treatment period and increased in all cases in the posttreatment period. In all cases, a net increase in overbite was observed. In the subgroup with vertical condylar growth, the overbite was found to increase in the treatment period in three cases; in two of these it decreased subsequently in the posttreatment period. In another case the overbite decreased both during the treatment and posttreatment periods. In the remaining cases, the overbite decreased and subsequently increased. In this group net increases or decreases were found.

Small and large initial overbite. The mean values of overbite of subgroups with sagittal direction of condylar growth were compared (Subgroup SCGs and Subgroup SCGI). At the end of treatment there was no significant mean difference between the two subgroups. However, at the final examination, the subgroup with small initial overbite was found to have a larger final overbite than the subgroup

Table 8.5. Mean values and standard deviations of the distance of the anterior maxillary incisor edge to palatal plane (Is-PP), the distance of anterior mandibular incisor edge to the mandibular plane (li-MP), and the changes in occlusal plane inclination ($OPx_1-x_2.RP1$), for the two subgroups with sagittal or vertical direction of condylar growth and a large initial overbite (Subgroups SCGI and VCGI).

Significance level; $n=8, t > 2.447, P < 0.05$.

	Subgroup SCGI n=3		Subgroup VCGI n=5			
Variable	Mean	S.D.	Mean	S.D.	t	Sign
Is-PP 2-1	0.8 mm	3.3	1.0 mm	0.7	0.148	NS
Is-PP 3-2	1.1 mm	1.3	1.4 mm	0.8	0.392	NS
Is-PP 3-1	1.8 mm	2.2	2.3 mm	1.1	0.449	NS
li-MP 2-1	-2.6 mm	2.4	-1.7 mm	1.0	0.770	NS
li-MP 3-2	1.8 mm	0.8	2.8 mm	1.3	1.151	NS
li-MP 3-1	-0.8 mm	1.7	1.1 mm	1.8	1.440	NS
OP2-1.RP1	5.7°	4.1	6.1°	2.0	0.778	NS
OP3-2.RP1	-2.6°	3.6	-2.6°	2.8	0.167	NS
OP3-1.RP1	3.1°	3.2	3.5°	3.2	1.218	NS

with a large initial overbite. This in contrast to the situation found in subgroups with vertical direction of condylar growth (Subgroup VCGI and Subgroup VCGs). Of these two subgroups the mean overbite in the subgroup with large initial overbite was larger at the three examinations.

An inspection of the tables of the individual values show no exceptions (Table 8.3).

8.3.3. Relationship of the direction of condylar growth to changes in the vertical positions of incisors and occlusal plane inclination

To evaluate if in the treatment of a large overbite the direction of condylar growth is of relevance to the changes in the occlusal plane and vertical position of incisors, the following analysis was undertaken. The changes in occlusal plane, the distance of the most anterior maxillary incisor edge to the palatal plane and the distance of the most anterior mandibular incisor edge to the mandibular plane were compared in the two subgroups with vertical or sagittal direction of condylar growth and a large initial overbite (Subgroup SCGI and Subgroup VCGI). The results are shown in Table 8.5. Table 8.6. shows the individual values in each subgroup.

Table 8.6. Individual changes in the distance of the most anterior maxillary incisor edge to the palatal plane (Is-PP), the most anterior mandibular incisor edge to the mandibular plane (li-MP) and the occlusal plane (OP) in Groups SCGI VCGI. (Distances in mm, occlusal plane inclination in degrees.)

Case	Subgroup SCGI		
	Is-PP 2-1	Is-PP 3-2	Is-PP 3-1
4251	-1.2	1.1	0.1
4799	4.7	-0.4	4.3
3269	-1.2	2.4	1.2
Mean	0.8	1.1	1.8
S.D.	3.3	1.3	2.2

Case	Subgroup VCGI		
	Is-PP 2-1	Is-PP 3-2	Is-PP 3-1
4657	1.6	2.1	3.8
3724	0.9	-0.1	0.8
4246	0.3	1.9	2.1
4243	1.9	1.3	3.2
5211	0.3	1.6	1.9
Mean	1.0	1.4	2.3
S.D.	0.7	0.8	1.1

Case	Subgroup SCGI		
	li-MP 2-1	li-MP 3-2	li-MP 3-1
4251	-5.1	2.3	-2.7
4799	-2.7	2.3	-0.4
3269	-0.1	0.9	0.8
Mean	-2.6	1.8	-0.8
S.D.	2.4	0.8	1.7

Case	Subgroup VCGI		
	li-MP 2-1	li-MP 3-2	li-MP 3-1
4657	-0.2	4.4	4.2
3724	-0.9	1.2	0.2
4246	-2.8	2.1	-0.7
4243	-2.6	3.9	1.3
5211	-1.8	2.5	0.7
Mean	-1.7	2.8	1.1
S.D.	1.0	1.3	1.8

Occlusal plane. The two subgroups with sagittal and vertical direction of condylar growth and deep overbite were compared. There was no significant difference between the two subgroups with respect to the mean changes in occlusal plane inclination in the treatment, posttreatment and total periods of the examination. Individual values (Table 8.6.) show no exceptional cases.

Distance of the most anterior maxillary incisor edge to the palatal plane. The mean differences in the distance between the two subgroups at various stages of examination were not significant. The tables of individual values show that in the

Table 8.6 continued:

Case	Subgroup SCGI			Case	Subgroup VCGI		
	OP2-1. RP1	OP3-2. RP1	OP3-1. RP1		OP2-1. RP1	OP3-2. RP1	OP3-1. RP1
4251	6	0	6	4657	4	-5	-1
4799	10	-7	3	3724	6	1	7
3269	2	-2	0	4246	6	-4	1
				4243	10	-5	5
				5211	6	0	6
Mean	5.7	-2.6	3.1	Mean	6.1	-2.6	3.5
S.D.	4.1	3.6	3.2	S.D.	2.0	2.8	3.2

subgroup with sagittal direction of condylar growth and a deep overbite, the distance decreased in two cases during the treatment period and increased in one. In the posttreatment period the distance increased in the two cases in which a decrease was found in the treatment period but it decreased in the remaining case. In contrast, in the subgroup with vertical direction of condylar growth and a deep overbite, the distance increased in all cases in the treatment period and decreased in one case in the posttreatment period.

Distance of the most anterior mandibular incisor edge to the mandibular plane.
The mean differences between the two subgroups at various stages were not significant. The inspection of the tables of individual values shows no exceptional cases.

8.3.4. Relationship of direction of condylar growth to intercanine width and anterior dental arch circumference

To examine the relationship of the direction of condylar growth to the changes in intercanine width and anterior arch circumference the mean values of these variables of cases with vertical or sagittal directions of condylar growth (Group SCG and Group VCG) were compared. The findings are shown in Table 8.7. The mean differences between the two groups were not significant with the exception of the mean difference between the net changes in mandibular intercanine width. It appears that a larger net mean increase in mandibular intercanine width occurred in the group with sagittal direction of condylar growth. The individual changes in mandibular intercanine width are shown in Figure 8.4.

Table 8.7. Mean values and distribution of individual values of circumference and intercanine width in the two groups with sagittal and vertical direction of condylar growth.
Significance level: $n=21$, $t>2.086$, $P<0.05$.

Variable		Group SCG n=8				Group VCG n=13				t Sign	
		Mean	S.D.	Range		Mean	S.D.	Range			
ICW U	2-1	1.46 mm	2.25	-2.8	4.2	2.29 mm	2.31	-2.7	4.0	0.813	NS
ICW U	3-2	-0.65 mm	1.56	-2.5	0.8	-1.61 mm	2.08	-2.4	0.6	1.116	NS
ICW U	3-1	0.80 mm	1.32	-2.7	3.1	0.68 mm	1.90	-2.6	3.2	0.120	NS
ICW L	2-1	1.9 mm	2.6	-3.4	4.2	0.8 mm	1.3	-1.3	3.4	1.214	NS
ICW L	3-2	1.3 mm	1.6	-4.0	1.7	-1.5 mm	1.2	-3.7	0.9	0.342	NS
ICW L	3-1	0.6 mm	1.8	-1.7	2.9	-0.7 mm	0.9	-2.3	0.9	2.117	P<0.05
Circum U	2-1	1.72 mm	4.30	-3.7	8.2	3.81 mm	1.97	-3.6	7.0	1.522	NS
Circum U	3-2	-0.44 mm	1.23	-2.7	0.8	-1.23 mm	1.22	-2.5	0.8	1.418	NS
Circum U	3-1	1.27 mm	3.33	-2.9	6.7	2.57 mm	1.99	2.8	5.9	1.126	NS
Circum L	2-1	3.36 mm	2.9	-0.1	7.7	2.75 mm	1.6	-0.5	4.9	0.636	NS
Circum L	3-2	-1.70 mm	0.9	-2.8	-0.2	-1.91 mm	1.4	-4.9	0.1	0.391	NS
Circum L	3-1	1.64 mm	2.2	-1.0	5.6	0.84 mm	1.4	-2.0	2.8	1.095	NS

* U and L denote the maxillary and mandibular arch respectively.

8.3.5. Mandibular plane inclination

The mean values and distribution of individual values are shown in Table 8.1.

The mean change in mandibular plane inclination for the sample of 21 cases was 1.24° with a standard deviation of 1.52° and a range of -4° to 4° . In the group with vertical direction of condylar growth the mean change in mandibular plane inclination was 2.69° with a standard deviation of 1.40° and a range of 1° to 4° . In the group with sagittal direction of condylar growth the mean change in mandibular plane inclination was -0.68° with a standard deviation of 1.70° and a range of -4° to 2° . The mean difference between the two groups was significant ($t=4.927$, $P<0.01$).

To evaluate the relationship of the net changes in mandibular plane inclination and direction of condylar growth, the correlation coefficient was calculated and found not significant ($r=-0.314$, $P>0.05$).

The correlation coefficient between the change in mandibular plane inclination and the values of overbite at successive stages of examination were calculated (Table 8.8).

Figure 8.4. The diagrams illustrate the changes in intercanine width found in Group SCG (sagittal direction of condylar growth) and Group VCG (vertical direction of condylar growth).

A significant correlation coefficient was found between the changes in mandibular plane inclination and the treatment changes in overbite and between the changes in mandibular plane inclination and the net changes in overbite.

The scatter diagram, Figure 8.5 shows that an increase in mandibular plane inclination and vertical condylar growth tend to be associated with a net increase in overbite, while a decrease in mandibular plane inclination and sagittal direction of condylar growth tend to be associated with a net decrease in overbite.

Table 8.8. Correlation coefficients between the changes in mandibular plane inclination and overbite.
Significance level: $n=21$, $r \geq 0.433$, $P \leq 0.05$.

Variable	Variable	n	r	Sign
MP3-1.RP1	overbite 1	21	0.141	NS
	overbite 2-1	21	-0.440	$P < 0.05$
	overbite 2	21	-0.060	NS
	overbite 3-2	21	-0.006	NS
	overbite 3	21	-0.110	NS
	overbite 3-1	21	-0.519	$P < 0.05$

Figure 8.5. Relationship of net overbite changes (overbite 3-1) to the changes in inclination of the mandibular plane (MP3-1.RP1). A third factor, the direction of condylar growth is indicated by different symbols.

8.4. Discussion

Björk (1960) classified deep overbite as dento-alveolar or basal deep overbite. A dento-alveolar deep overbite results from overeruption of upper and lower incisors and a vertical overdevelopment of the anterior regions of the maxillary and mandibular alveolar arches. A basal deep overbite may arise, by forward rotation of the mandible in relation to the maxilla. He distinguishes three types of forward rotation, (I, II and III) according to the site where the centre of rotation is located. In Type I, the centre is at the temporomandibular joints, in Type II at the incisal edges of the lower incisors and in Type III, at the premolars. Björk (1969) states that a Type I forward rotation resulting in deep overbite may be caused by occlusal imbalance due to loss of teeth, malocclusion or a powerful musculature. The remaining part of the dentition is then vertically unstable and the two dental arches may be pressed into each other. In Type II, the incisal occlusion is normal and the centre of rotation is at the incisal edges of the lower incisors. No overbite develops in this type. In the case of an abnormal incisal occlusion, rotation may occur with the centre at the premolars, resulting in the development of a deep overbite (Type III). In Type II and III, a more pronounced development of the posterior facial height results in a forward rotation of the mandible. The main cause of the development of the posterior facial height is the vertically directed growth at the mandibular condyles (Björk, 1969).

While it is not possible, in retrospect, to determine with certainty the aetiology of the deep overbites in the present investigation, it seems likely that cases with a more sagittal direction of condylar growth were of dento-alveolar type or were deep overbites, with a Type I forward rotation of the mandible. The cases with a vertical direction of condylar growth and a deep overbite probably had a Type I forward rotation or a combination of Types I and III.

In the present study the direction of condylar growth was determined between the initial and final examination. The end of treatment examination was not used for the reasons already given. Therefore it is not possible, from this study, to obtain direct evidence that the direction of condylar growth was altered as a result of treatment. Several studies with experimental animals (Moffett, 1971) have demonstrated that changes in the growth of the condylar cartilages may result from the use of Class II intermaxillary elastic traction. However, we are of the opinion that the duration and intensity of treatment are unlikely to produce a permanent change in the direction of condylar growth and thus influence our results.

From the results shown in Tables 8.3 and 8.4, it appears that the response of the deep overbite to treatment differs significantly between the different subgroups (Subgroup SCGI and Subgroup VCGI). The overbite in those cases in which a sagittal direction of growth occurred was significantly smaller at the end of treatment and at the final examination. It therefore appears that the direction of condy-

Figure 8.6. The results of treatment in a case with a sagittal direction of condylar growth and a deep overbite (case 4251). From left to right, are the profile and dental casts of the initial examination, the casts at the removal of the fixed appliance, and the profile and casts at the final examination. The figure of the superimposition on the SN plane registered at S shows the overall changes. The mandibles, superimposed on mandibular natural reference structures illustrate the vertical direction of condylar growth.

Figure 8.7. The results of treatment in a case with vertical direction of condylar growth and a deep overbite (case 4243). From left to right, are the profile and dental casts of the initial examination, the casts at the removal of the fixed appliance, and the profile and casts at the final examination. The figure of the superimposition on the SN plane registered at S shows the overall changes. The mandibles, superimposed on mandibular natural reference structures illustrate the vertical direction of condylar growth.

lar growth may be related to the correction of a deep overbite. Furthermore, the results suggest that the direction of condylar growth may be of importance in predicting the prognosis of the treatment of deep overbite. The findings on the two subgroups with small initial overbites are not consistent with those on subgroups with large overbites. As, the final mean overbites in the subgroup with a vertical direction of condylar growth was found to be significantly smaller than the mean overbite in the subgroup with a sagittal direction of condylar growth. However, it is noteworthy that only in this subgroup (Subgroup VCGs) were cases found in which overbite increased in the treatment period and decreased in the posttreatment period.

Evidence presented in the literature and the results of the present study, indicate a direct cause and effect relationship between the direction of condylar growth and overbite. A relationship between mandibular plane inclination and overbite was also found. However, it seems unlikely that there is a direct causal relation.

The investigation of the vertical changes in occlusal plane and the positions in the two subgroups (Subgroup SCGI and Subgroup VCGI) with deep overbites provides further insight into the changes which occur when a deep overbite is treated. However, as the changes were similar in both subgroups, no further information was gained concerning the cause of overbite stability or relapse. Thus, the direction of growth is the determining factor involved.

An increase in mandibular intercanine width during treatment may be more adequately maintained in patients with a sagittal direction of condylar growth. Similar findings were not, however, apparent for changes in maxillary intercanine width or dental arch circumference. No obvious explanation is available for these findings.

Finally, it may be concluded that there is a relationship between the long term results of treatment of deep overbite and the direction of condylar growth, a more successful reduction of a deep overbite occurred when the growth of the condyles was in a sagittal direction.

mandibular rotation

9.1. Introduction

Rotation of the mandible has been found by Björk (1969) to be masked, when it is examined using conventional superimposition with the lower border of the mandible as reference. This masking of the rotation of the mandible is caused by the remodelling taking place at the lower border of the mandible (Björk 1963). Björk (1969) proposed that for clinical purposes the growth rotation of the mandible be evaluated using the structural method of superimposition. Growth rotation of the mandible in relation to the sella nasion line, can be read from the angle between the sella nasion lines for two different ages. In the present investigation the rotation of the mandible is considered to be due to a combination of mandibular growth and the effects of treatment.

Mandibular rotation will be examined and its relationship evaluated to the direction of condylar growth, overbite, overjet, intercanine width, anterior dental arch circumference, occlusal plane inclination, and the posttreatment interval.

9.2. Method

9.2.1. Measurement

In this part of the investigation the same 21 cases were used as for the evaluation of direction of condylar growth (Chapter 8). The technical details of the method used in the present study are described in Chapter 2.3.7. Definitions of the points and planes are given in Chapter 2.3. The method of measurement is illustrated in Figure 9.1.

Figure 9.1. The method used to determine the mandibular rotation (MR) as represented by the angle between SN1 and SN3 when the two mandibles are superimposed on the natural reference structures in the mandible. Solid line represents the initial examination and the dotted line the final examination. This is an example of forward mandibular rotation between initial and final examinations.

MR Mandibular rotation, was measured as the angle between two sella nasion planes of the different stages of the examination when the two mandibles were superimposed on the reference structures. A negative value indicates a forward rotation and a positive value a backward rotation.

9.2.2. Procedure of analysis

The same procedure as used in Chapter 8.2 and illustrated in Figure 8.1 was used to analyse the group of 21 cases. Thus differences between the two groups: Group SCG (sagittal direction of condylar growth) and Group VCG (vertical direction of condylar growth) and the four subgroups regarding mandibular rotation were evaluated.

Table 9.1. Mandibular rotation, mean values and distribution of individual values.
Significance level: $n=21$, $t \geq 2.845$, $P \leq 0.01$.

Variable	n	Mean	S.D.	Range	t	Sign
MR 2-1	21	-0.55°	2.7	-5 to 6	0.883	NS
MR 3-2	21	-2.56°	3.6	-5 to 0	6.400	$P < 0.01$
MR 3-1	21	-3.11°	1.8	-9 to 3	3.887	$P < 0.01$

9.3. Results

9.3.1. Mean values and distribution of individual values

Mean values, standard deviations and ranges of the measurements made are shown in Table 9.1. The individual values of the measurements are shown in Table 9.2. and correlation coefficients in Table 9.3.

During the treatment period, the mean mandibular rotation was not found to be significant. Individual changes however ranged from -5° (forward rotation) to 6° (backward rotation). In the posttreatment period the mean mandibular rotation was found to be significant. A mean forward rotation of -2.56° with a standard deviation of 3.6° occurred and the individual changes ranged from -5° to 0° . A net mean rotation of -3.11° with a standard deviation of 1.8° and range from -9° to 3° was found to be significant. The tables of the individual values (Table 9.2) show that during treatment backward mandibular rotation occurred in 8 cases, a forward rotation in 12 cases, and in one case there was no change. Of the eight cases, seven had a forward rotation during the posttreatment period and in one, no change was found. All twelve cases with forward rotation had a further forward rotation in the posttreatment period. Thus, in the posttreatment period 20 cases had a forward rotation and in one case no rotation was found to occur. Sixteen cases had a net forward rotation. In one case there was no change and in four cases a net backward rotation occurred. These five cases had a backward rotation during the treatment period.

Correlations. There was no evidence of a relationship between mandibular rotation in the treatment and posttreatment periods. The correlation coefficient between mandibular rotation in the treatment period and the net mandibular rotation was found to be significant as was the correlation between mandibular rotation in the posttreatment period and the net mandibular rotation.

9.3.2. Relationship of mandibular rotation to the direction of condylar growth.

Table 9.2. Individual values of mandibular rotation (degrees). Divided according to condylar growth direction and initial overbite.

Subgroup SCGI: large initial overbite and sagittal condylar growth.

Subgroup SCGs: small initial overbite and sagittal condylar growth.

Subgroup VCGI: large initial overbite and vertical condylar growth.

Subgroup VCGs: small initial overbite and vertical condylar growth.

Case	Subgroup SCGI		
	MR 2-1	MR 3-2	MR 3-1
4251	2	-4	-2
4799	1	-1	1
3269	1	0	1
mean	1.3	-1.4	0.0
S.D.	0.8	2.0	1.2

Case	Subgroup VCGI		
	MR 2-1	MR 3-2	MR 3-1
4657	2	-3	0
3724	-4	-4	-8
5211	-5	-4	-9
4243	2	-2	-1
5211	-2	-5	-7
mean	-1.4	-3.5	-4.9
S.D.	3.4	1.1	4.1

Case	Subgroup SCGs		
	MR 2-1	MR 3-2	MR 3-1
3170	2	-1	1
4445	-1	-1	-2
3473	-2	-2	-4
3430	-3	-2	-6
3614	6	-3	3
mean	0.3	-2.0	-1.6
S.D.	3.5	3.4	0.6

Case	Subgroup VCGs		
	MR 2-1	MR 3-2	MR 3-1
3470	0	-3	-3
4697	-3	-3	-5
4923	-3	-1	-4
5076	-3	-3	-6
5074	-1	-4	-5
5170	3	-4	-2
3679	-2	-4	-6
5013	-3	-5	-8
mean	-1.3	-2.6	-3.9
S.D.	2.0	3.4	2.5

Table 9.3. Correlation coefficients for mandibular rotation.

Significance level: $n=21$, $r>0.632$, $P<0.01$.

Variable	Variable	n	r	Sign
MR 2-1	MR 3-2	21	0.108	NS
	MR 3-1	21	0.838	$P<0.01$
MR 3-2	MR 3-1	21	0.632	$P<0.01$

Table 9.4. Mean values of mandibular rotation, and the distribution of individual values of the two groups in which sagittal and vertical condylar growth occurred.
Significance level: $n=21$, $t \geq 2.093$, $P \leq 0.05$.

Variable	Group SCG				Group VCG				t	Sign
	Mean	S.D	Range		Mean	S.D.	Range			
MR 2-1	0.75°	2.7	-3	6	-1.35°	2.5	-5	3	1.796	NS
MR 3-2	-1.84°	1.2	-4	0	-3.01°	2.1	-5	-1	1.414	NS
MR 3-1	-1.08°	2.8	-6	3	-4.36°	3.6	-9	0	2.177	P<0.05

The sample was divided into two groups: Group SCG (eight cases with a sagittal direction of condylar growth) and Group VCGI (13 cases with a vertical direction of condylar growth). The determination of the direction of condylar growth is described in chapter 2.3 and 8.2. The mean differences of mandibular rotation in these two groups were then evaluated, using the t-test (Table 9.4). The changes in mandibular rotation in the two groups are illustrated in Figure 9.2.

Mandibular rotation in the two groups in the treatment and posttreatment periods was not found to be significantly different. However, the mean difference between the net mandibular rotation of the two groups was significant. This indicates that forward rotation of the mandible was on average greater in the group with a vertical direction of condylar growth. In this group the net mean forward rotation was -4.36 degrees with a standard deviation of 3.6° and range from -9° to 0°. In the group with a sagittal direction of condylar growth the mean value was -1.08°, with a standard deviation of 2.8° and range from -6° to 3°.

9.3.3. Relationship of mandibular rotation, direction of condylar growth and overbite

As described in Chapter 8, and illustrated in Figure 8.3 the sample was subdivided into four subgroups according to vertical or sagittal direction of condylar growth and small or large overbite: the four subgroups were compared to evaluate differences in direction and amount of mandibular rotation. None of these differences were found to be significant.

The individual values were examined (Table 9.2.). In group SCGI all three cases had a backward rotation of the mandible during treatment and a forward rotation was found in two cases following treatment. In one case no change was found to occur following treatment. In Subgroups SCGs, VCGI and VCGs instances of backward rotation were found to occur during treatment. Generally a forward rotation occurred both during and following treatment in these three groups.

Figure 9.2. Differences in mandibular rotation occurring in Group SCG (sagittal condylar growth) and Group VCG (vertical condylar growth).

9.3.4. Correlations

The correlation coefficients calculated between mandibular rotation and overbite were not significant. This was also the case for the mandibular rotation and overjet, anterior dental arch circumference, intercanine width, occlusal plane and the posttreatment interval.

9.4. Discussion

The principle findings of the examination of mandibular rotation are that during treatment no significant mean rotation of the mandible took place while in the posttreatment period a significant mean forward rotation occurred. These changes were not found to be correlated. In the treatment period a backward rotation was found to occur in eight cases, in one case no rotation occurred and in 12 cases a forward rotation took place. In contrast to the treatment changes the posttreatment period is characterised by a forward rotation in all cases except one.

Björk and Skieller (1972), found in 21 untreated subjects with various malocclusions, who were examined over a six year period around puberty, that forward rotation occurred in 19 cases and backward rotation in 2 cases. In a previous report Björk (1969) found that backward rotation was less frequent than forward rotation. Further that backward rotation may be due to a raising of the bite by orthodontic means or it may occur when condylar growth is in a sagittal direction. In the present investigation, the cases in which backward rotation occurred during treatment are distributed within both groups (SCG and VCG) and it appears that backward rotation may be due to the effects of treatment or in some instances to treatment combined with a sagittal condylar growth.

Odegaard (1970) investigated the influence of treatment on the degree of mandibular rotation in 26 subjects in which implants had been placed in the mandible. Nine subjects were not treated, 17 subjects received treatment with either fixed or removable appliances. Odegaard concluded that the degree of rotation was influenced by treatment. Our findings show that during the treatment period forward as well as backward rotation occurred. While in the posttreatment period all cases except one showed forward rotation. This difference is circumstantial evidence of the influence of treatment on mandibular rotation.

Björk and Skieller (1972), found a relationship between the direction of condylar growth and mandibular rotation. In our study, the correlations between these variables were found to be not significant. However, a significant mean difference in the net mandibular rotation was found between the groups with a sagittal or vertical direction of condylar growth. The forward rotation was less in the group which has subjects with sagittal condylar growth, indicating a relationship of the degree of mandibular rotation to the direction of condylar growth. It seems likely that the effect of treatment reduces the significance of their relationship by an alteration in the degree of mandibular rotation. The mean differences between the two subgroups with large overbite were not observed to be significant. However, the individual values indicate some differences. These differences suggest that a relationship between the rotation of the mandible and overbite still may have existed. This expected relationship was however not directly evident. The reason may be the influence of a second predominant factor, that of the direction of condylar growth. The direction of condylar growth was found to be statistically different between the two subgroups (SCGI and VCGI).

Björk and Skieller (1972), found a significant relationship between mandibular rotation and overbite. The present findings on the mandibular rotation in the posttreatment period do not confirm a relationship to the overbite changes and it seems likely that the direction of condylar growth was possibly a more important factor.

The findings on the relationship of mandibular rotation to changes of overbite, overjet, intercanine width, anterior dental arch circumference and occlusal plane inclination were all found to be not significant. It may therefore be concluded that mandibular rotation does not appear to be related to these individual variables but rather to a complex of factors that cause mandibular rotation. One of these factors is probably condylar growth, other factors could not be individually identified.

facial profile

10.1 Introduction

One of the aims of orthodontic treatment may be the improvement of the aesthetic appearance. Treatment of a malocclusion is beneficial to the general facial appearance although adverse effects on the soft tissue profile have been reported.

This part of the study was to evaluate the changes in the facial profile in subjects treated with the Begg technique. Changes in the facial profile were examined in two stages: firstly the soft tissue profiles at the initial examination were evaluated by a method of subjective inspection, to divide the sample into groups with similar profiles; then by a subjective inspection of the profiles and objectively by measurement.

10.2 Method and measurements

The profiles were investigated at the initial and final examinations. The intermediate stage was not investigated as it was felt that the maturation of the profile over the total period of observation was of primary interest.

10.2.1 Division of sample

In dividing a sample into groups of similar profiles two methods may be used: an objective or a subjective method. With the subjective method a certain profile measure is selected as basis for the classification. If this procedure is used the influence of other contributing profile components is neglected. In the subjective method the profiles are classified by inspection (Cox and van der Linden 1971, de Laat 1974). This method has obvious disadvantages. However, all the various components which contribute to the anterior facial profile are considered and not just a single factor. For this reason the subjective method was chosen for this study.

Table 10.1. Definitions of the dento-skeletal and soft tissue anterior profile measurements.

Variable	Definition
S.N.A.	Point A, relative to the SN plane
S.N.B	Point B, relative to the SN plane
A.N.B	Sagittal jaw discrepancy
S.N.Pg	Point Pg, relative to the SN plane
N.A.Pg	Angle of convexity of the skeletal profile
Is-NPg	Shortest distance from the most anterior maxillary incisor edge (Is) to the facial plane (NPg).
li-NPg	Shortest distance from the most anterior mandibular incisor edge (Is) to the facial plane (NPg)
overbite	Defined in Chapter 3.2
MR	Mandibular rotation is defined in Chapter 9.2
Ar3—1.RPI	Direction of condylar growth is defined in Chapter 8.2
na.no.pg	Soft tissue profile convexity including the nose (no)
na.a.pg	Soft tissue profile convexity
a.na.b	Sagittal soft tissue profile discrepancy
Pg.N.no	Nose (no) relative to the facial plane (NPg)
Pg.N.a	Upper lip (a) relative to the facial plane
Pg.N.Is	Upper lip (Is) relative to the facial plane
Pg.N.li	Lower lip (li) relative to the facial plane
Pg.N.b	Lower lip (b) relative to the facial plane
Pg.N.pg	Chin (pg) relative to the facial plane

An inspection of the initial profile photographs of all subjects was made by five orthodontists and two laymen. The seven examiners were invited to inspect the profiles and to group the profiles which were most similar. Each examiner made his inspection independently of the other examiners. In this way, three groups could be identified. In some cases there was disagreement regarding the classification. After reexamination these cases were assigned to one of the groups. Two profiles differed from all other profiles and were excluded from further examination.

10.2.2 Measurements

The cephalometric measurements of the soft tissue and dento-skeletal profile of each group were compared. The reference points and planes used for the cephalometric measurements are defined in Chapter 2.3. and illustrated in Figures 2.2., 2.3. and 2.4. The measurements and their definitions are listed in Table 10.1.

10.3. Results

The soft tissue profiles are illustrated in Figure 10.1. The three groups are coded as follows, according to characteristics at the initial examination: Group PC profiles are convex (aesthetically poor); Group PM profiles are convex and the mandible appears prominent (aesthetically acceptable) ; Group PS profiles are straight (aesthetically acceptable).

In Group PC there were 14 cases; all malocclusions were Class II division 1. In Group PM there were five cases; all malocclusions were classified as borderline. In Group PS there were nine cases; seven were Class I and two were Class II division 1 malocclusions.

10.3.1. Soft tissue profile description

The characteristics of each group will be described; they may also be studied from Figure 10.1 where the initial and final profiles are shown of each subject superimposed on the facial plane and orientated to the mid-point between the lips.

Initial examination.

Group PC. The profiles appear convex, the mandible appears retrognathic, the lips protrude and are parted at rest. In some cases the nose appears prominent.

Group PM. The profiles appear convex, the chin is more prominent in relation to the face than Group PC and is well defined. The nose appears small. Lips are prominent and in contact at rest.

Group PS. The profiles tend to be straighter than in the other two groups. The lips are generally in contact at rest and the chin is well defined.

Final examination

The inspection of the profiles at the final examination reveals that the groups established at the initial examination are readily recognizable.

Group PC. The profiles are generally convex and the mandibles appear retrognathic. The lips appear protruded and are in contact at rest.

Group PM. The profiles appear less convex than at the initial examination. The lips are also less prominent than at the initial examination and the chin is well defined.

Group PS. The lips appear less prominent in relation to the face than at the initial examination and the chin is well defined.

10.3.2. Cephalometric measurements

Initial examination

The mean values and distribution of individual values are shown in Table 10.2.

Figure 10.1 The anterior soft tissue profiles of initial and final examinations superimposed on the facial plane NPg and registered on the midpoint between the lips. Group PC convex profiles; aesthetically poor. Group PM convex profiles with prominent mandibles; aesthetically acceptable. Group PS straight profiles; aesthetically acceptable.

and 10.3. The mean differences between the groups were evaluated using the t-test.

Dento-skeletal profile. At the initial examination the mean S.N.A angle in Group PS was found to be significantly smaller than the mean S.N.A angle in Groups PC and PM. The mean difference between Groups PC and PM was not significant. The findings indicate that point A is less prominent relative to the sella nasion plane in Group PS. The mean angles S.N.B and S.N.Pg were significantly larger in Group PM than in Groups PC and PS. Further, no significant differences were found between Group PC and PS. These findings indicate that point B and point Pg are more prominent relative to the sella nasion plane in Group PM and that they are similar in Groups PC and PS. The differences in the sagittal positions of points A, B and Pg results in Group PC having the largest mean sagittal jaw discrepancy (A.N.B) and the greatest convexity of the skeletal profile (N.A.Pg).

If Groups PC and PS are compared then it appears that the greater convexity, (N.A.Pg) and sagittal jaw discrepancy (A.N.B) found in Group PC are due to a more anterior positioning of point A relative to the sella nasion plane. Group PM differs from both Groups PC with respect to a more anterior position of the points B and Pg relative to the sella nasion plane.

The mean positions of the incisal edges of the maxillary and mandibular incisors relative to the facial plane (Is-NPg, li-NPg) were significantly different in Groups PC and PS. In Group PC the incisal edges were more anteriorly positioned. In the comparison of Group PC with Group PM the maxillary incisors were more prominent in Group PC and no significant difference was found in the position of the mandibular incisal edges. No significant differences were observed between Groups PM and PS. No difference in overbite was found between the three groups.

Soft tissue profile. The characteristics of the soft tissue profile generally reflect the contour of the underlying hard structures. The soft tissue profile convexity (na.a.pg) was found to be greatest in Group PC, and no significant difference was found between Group PM and PC. Similar findings apply to the sagittal profile discrepancy (a.n.b). The measurements relating the most anterior point of the nose to the face (na.no.pg, Pg.N.no) indicate that the nose is more prominent in Group PC than in the other two groups. The upper lip (Pg.N.a, Pg.N.ls) was found to be most prominent relative to the facial plane in Group PC and least prominent in Group PS. The position of the lower lip relative to the facial plane (Pg.N.li, Pg.N.b) was not found to differ significantly in the three groups. A difference in the position of the chin (Pg.N.pg) was found between Group PC and PM.

If the skeletal, dental and soft tissue characteristics are collectively considered it appears that the differences between Groups PC and PS are due to a more anterior position of the middle facial structures in Group PC. The anterior border of the mandible appears more anteriorly positioned relative to the sella nasion plane in

Table 10.2. Soft tissue profile, Examination 1 (angular measurements, in degrees)

Level of significance: $n = 14$, $t \geq 2.179$, $P \leq 0.05$; $t \geq 3.055$, $P \leq 0.01$.

$n = 19$, $t \geq 2.110$, $P \leq 0.05$; $t \geq 2.898$, $P \leq 0.01$.

$n = 23$, $t \geq 2.069$, $P \leq 0.05$; $t \geq 2.807$, $P \leq 0.01$.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PS
na.no.pg	127.2	3.6	120	132	133.1	2.4	131	136	130.5	3.7	124	132	3.379	2.144	1.366
na.a.pg	156.2	4.1	149	163	160.8	2.6	158	165	163.5	4.0	159	170	1.945	3.710	1.354
a.na.b	11.5	1.8	9	15	10.0	0.7	9	11	8.6	1.5	5	10	1.818	3.978	1.878
Pg.N.no	40.6	1.8	39	45	36.2	2.2	33	39	37.3	2.2	35	42	4.470	3.924	0.894
Pg.N.a	19.4	1.9	17	22	17.2	1.8	15	20	15.1	1.6	13	16	2.176	5.538	2.263
Pg.N.ls	20.3	2.0	17	24	17.4	1.9	15	20	16.2	1.8	14	19	2.701	4.858	1.193
Pg.N.li	12.7	2.3	10	15	12.8	1.6	11	15	11.1	1.8	7	13	0.069	1.734	1.695
Pg.N.b	5.8	1.4	3	8	5.2	1.3	4	7	4.9	0.9	4	5	0.770	1.756	0.631
Pg.N.pg	6.5	0.9	5	8	5.1	1.1	3	6	5.8	1.1	4	8	2.656	1.510	1.211

Table 10.3. Anterior dento-skeletal measurements at the start of treatment. (angular measurements in degrees, linear measurements in mm)

level of significance the same as for table 10.2.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PS
S.N.A.	81.0	1.8	73	86	81.7	4.6	78	89	77.1	1.8	74	80	2.963	0.432	2.794
S.N.B.	74.8	2.0	68	78	80.0	3.4	76	85	73.9	2.0	71	77	0.830	3.294	4.263
A.N.B.	6.2	1.7	4	9	1.8	1.4	0	4	3.2	1.7	0	7	4.163	5.185	1.508
S.N.Pg	75.6	2.1	67	69	81.2	3.6	77	86	75.3	2.1	73	80	0.455	3.351	3.876
N.A.Pg	168.8	3.8	163	176	177.6	1.9	175	179	175.1	3.8	167	179	3.371	4.005	1.352
Ii-NPg	5.6	3.5	-0.3	12.6	4.5	2.0	2.7	7.3	1.9	3.0	-3.2	4.4	2.462	0.608	1.660
Is-NPg	14.2	3.2	7.2	17.8	9.8	2.6	7.6	14.3	8.5	3.9	0.7	10.5	3.731	2.722	0.609
Overbite	4.1	1.6	0.9	7.1	3.7	2.1	0.5	5.4	2.8	1.7	0.5	4.9	1.691	0.403	0.785

Table 10.4. Soft tissue profile changes between initial and final examination (in degrees).

Level of significance the same as for table 10.2.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PS
na.no.pg	-1.1	2.9	-6	4	-1.7	6.1	-9	6	0.1	2.7	-4	1	0.261	0.959	0.730
na.a.pg	6.6	3.0	-1	10	4.5	4.4	-1	9	5.9	3.9	1	13	1.180	0.502	0.594
a.na.b	-2.7	1.4	-5	0	-1.6	1.3	-4	1	-1.7	2.0	-4	1	1.231	1.640	0.039
Pg.N.no	0.3	1.5	-3	3	0.8	4.3	-5	5	-0.4	2.3	-3	3	0.407	0.798	0.666
Pg.N.a	-3.0	1.4	-5	0	-3.3	2.4	-5	0	-2.5	1.7	-6	-1	0.268	0.779	0.697
Pg.N.ls	-3.3	1.3	-6	-1	-2.9	2.1	-5	0	-2.8	1.6	-5	-1	0.576	0.881	0.084
Pg.N.li	-0.5	1.9	-6	1	-2.2	1.5	-4	-1	-1.6	1.4	-3	1	1.752	1.467	0.695
Pg.N.b	-0.2	0.9	-2	1	-1.5	0.6	-2	-1	-0.8	0.8	-2	0	2.789	1.508	1.597
Pg.N.pg	0.2	0.7	-1	1	-0.1	0.5	-1	1	-0.1	0.5	-1	1	0.711	0.269	0.552

Table 10.5. Anterior dento-skeletal changes between initial and final examinations (angular measurements in degrees, linear measurements in mm).
Level of significance the same as for table 10.2.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PS
S.N.A.	-1.8	1.9	-6	0	-0.4	2.3	-3	2	-0.9	1.0	-2	1	1.249	1.328	0.591
S.N.B.	0.8	1.3	-1	3	0.7	1.9	-2	2	1.1	1.8	-2	4	0.182	0.449	0.428
A.N.B.	-2.6	1.3	-5	0	-1.1	1.1	-2	0	-2.1	1.4	-4	0	2.244	0.941	1.269
S.N.Pg	1.3	1.6	-1	4	2.0	1.8	-1	4	2.4	2.0	-1	5	0.808	1.378	0.307
N.A.Pg	5.9	3.7	0	11	-1.3	2.6	-3	3	0.3	5.6	-5	10	3.881	2.836	0.588
li-NPg	-2.6	2.4	-6.1	1.1	-4.2	1.3	-6.1	-2.8	-4.0	2.5	-7	-0.8	1.346	1.281	0.160
ls-NPg	-7.4	2.7	-12.0	-3.6	-6.3	2.1	-9.5	-4.1	-7.5	3.4	-12.2	-1.2	0.808	0.062	0.681
overbite	0.7	1.7	-4.8	1.2	0.8	1.5	-2.6	1.2	0.7	1.7	-1.8	1.2	0.107	0.699	0.812
MR	1.9	3.5	-1	6	4.4	2.9	0	7	4.1	3.2	-1	9	1.209	1.171	0.161
Ar3-1.MPI	129.2	18.9	94	151	129.9	11.5	113	137	129.9	12.2	117	145	0.067	0.078	0.006

Table 10.6. Soft tissue profile, final examination (angular measurements in degrees).
Level of significance; the same as for table 10.2.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PC
na.no.pg	126.0	2.6	120	130	131.5	4.4	127	138	130.6	3.8	123	137	3.301	3.371	0.389
na.a.pg	162.8	3.7	159	174	165.3	3.7	159	169	169.4	4.7	163	174	1.250	3.654	1.658
a.na.b	8.9	1.2	7	11	8.4	1.9	5	11	6.9	1.6	5	10	0.668	3.195	1.450
Pg.N.no	40.9	1.8	38	45	37.0	3.6	35	40	36.9	3.0	35	41	3.101	3.934	0.061
Pg.N.a	16.4	2.0	15	21	13.6	1.4	12	15	12.6	1.8	11	16	2.450	4.588	1.471
Pg.N.ls	17.0	2.3	14	22	14.6	1.3	13	16	13.4	1.5	11	16	2.161	4.053	1.425
Pg.N.li	12.2	1.6	10	16	10.6	0.7	10	11	9.5	1.2	8	10	2.093	4.222	1.801
Pg.N.b	5.6	1.2	3	8	3.7	0.9	3	5	4.5	0.6	3	5	2.966	3.352	0.756
Pg.N.pg	6.7	0.8	5	8	5.0	0.9	3	6	5.9	1.1	4	7	3.737	1.816	1.543

Table 10.7. Dental and Skeletal measurements final examination (Angular measurements in degrees, linear measurements in mm).
Level of significance; the same as for table 10.2.

Variable	Group PC n=14				Group PM n=5				Group PS n=9				t	t	t
	Mean	S.D.	Range		Mean	S.D.	Range		Mean	S.D.	Range		PC-PM	PC-PS	PM-PC
S.N.A.	79.2	3.2	74	85	81.5	2.8	80	86	76.1	2.0	72	80	1.371	2.468	4.024
S.N.B.	75.6	2.8	71	81	80.7	2.1	79	84	75.0	2.6	70	78	3.599	0.523	4.051
A.N.B.	3.6	1.4	0	6	0.8	0.7	0	2	1.1	1.4	-1	3	3.988	3.783	0.566
S.N.Pg	77.0	2.6	72	81	83.3	2.5	81	87	77.6	2.6	73	81	4.591	0.505	3.908
N.A.Pg	174.6	3.1	167	178	176.3	0.8	176	178	175.5	3.6	171	180	1.172	0.580	0.578
li-NPg	2.7	2.6	-2.0	7.3	0.3	1.5	-1.9	2.2	-2.1	2.4	-5.4	1.7	1.839	4.245	1.922
ls-NPg	6.8	2.1	3.5	11.0	3.4	1.7	0.4	4.8	1.0	2.6	-2.5	4.0	3.128	5.739	1.795
overbite	3.3	1.8	0.7	4.6	2.8	1.5	1.7	5.3	2.5	1.3	0.3	6.2	0.507	1.059	0.363

Group PM than in the other two groups. In addition, maxillary structures appear more anteriorly positioned in Group PM than in Group PS.

Changes between initial and final examination.

The mean changes and distribution of individual values are shown in Table 10.4 and 10.5.

Dento-skeletal changes. The mean changes in the angles S.N.A, S.N.B and S.N.Pg were not found to differ significantly in the three groups although when the changes of the points A, B and Pg are expressed collectively as the changes in sagittal jaw discrepancy and skeletal convexity it was found that the mean sagittal jaw discrepancy decreased more in Group PC than Group PM. The skeletal convexity decreased by the greatest amount in Group PC.

The findings shown in Table 10.5 indicate that the changes in sagittal jaw discrepancy and skeletal convexity result from a combination of changes. In Group PC they were generally due to a decrease in S.N.A and an increase in S.N.B and S.N.Pg. In Groups PM and PS, increases in S.N.A also occurred, and in these two groups decreases in A.N.B were due to relatively greater increases in S.N.B. than SNA or due to a decrease in S.N.A and an increase in S.N.B. The mean changes in distance of the incisor edges relative to the facial plane (Is-NPg, li-NPg) were not found to be statistically different for the three groups. The incisors tended to become less prominent relative to the facial plane in all three groups. No significant differences in the changes in overbite, mandibular rotation or direction of condylar growth were observed.

Soft tissue profile. The mean changes in the soft tissue profile were not found to differ significantly in the three groups, with the exception of the angle Pg.N.b where the difference between Group PC and PA was significant. (Table 10.4) The examination of the measurements indicating the position of the nose relative to the face shows that in all three groups the range of values are similar, slight increases or decreases in the prominence of the nose relative to the face were found to occur (na.no.pg, Pg.N.no). Upper lip (Pg.N.a, Pg.N.ls) and lower lip (Pg.N.li, Pg.N.b) were found to become less prominent in all three groups relative to the facial plane. The changes in the position of the chin (Pg.N.pg) appear minimal. Thus, it appears that in all three groups the lips become less prominent relative to the chin and nose.

Final Examination.

The mean and individual values are shown in Table 10.6 and 10.7.

Dento-skeletal profile. At the final examination the mean S.N.A angle was smallest in Group PS, and the difference between Groups PC and PM was not found to be significant. The mean of the angles S.N.B and S.N.Pg were not found to be

significantly different between Groups PC and PS. These mean values were largest in Group PM. The mean A.N.B angle was largest in Group PC and no significant difference was found between Groups PM and PS. The mean N.A.Pg angle was not found to be significantly different for any specific group. Maxillary incisors were most prominent relative to the facial plane in Group PC and least in Group PS. The difference in overbite, was not found to differ significantly between the three groups.

Soft tissue profile. In the comparison of the soft tissue profiles it was found that for all aspects examined the mean differences between Groups PM and PS were not significant. With the exception of the position of the chin (Pg.N.pg) it was found that all measurements denoting the positions of the nose and lips differed significantly between Groups PC and PM and between Groups PC and PS. These findings indicate that relative to the facial plane the nose and lips were more protruded in Group PC than in the other groups. The mean sagittal soft tissue profile discrepancy was significantly different in Groups PC and PS although no significant difference was found between Groups PC and PM. The convexity of the soft tissue profile was significantly different between Groups PC and PS. No difference was found between Groups PC and PM. Group PC was shown to have the most convex profile.

If the soft tissue, skeletal and dental measurements are collectively evaluated it appears that when Groups PC and PS are compared the structures of the middle third of the face, including the lips are more anteriorly positioned in Group PC than Group PS. In comparing Group PC and Group PM it appears that relative to the facial plane the soft tissue structures are all more prominent in Group PC. However, relative to the sella nasion plane the skeletal points Pg and B are more prominent in Group PM. Point A is similar in the two groups. This means that the mandibular structures in Group PC are retrognathic when compared with Group PM. Groups PM and PS differ in respect to the skeletal structures. Relative to the sella nasion plane the points A, B and Pg are less prominent in Group PS. The measurements of the soft tissue profile were not shown to be significantly different.

10.3.3 Relationship between dento-skeletal and soft tissue profile changes

The correlation coefficients between the changes in dento-skeletal and the soft tissue profile were calculated (Table 10.8). The correlations between the changes in S.N.A, S.N.B, N.A.Pg, and S.N.Pg and the soft tissue profile measurements were with one exception not found to be significant. The correlations between A.N.B changes and changes in Pg.N.a, na.a.pg and a.n.b were found to be significant. The correlations indicate that a decrease in sagittal jaw discrepancy is associated with a decrease in sagittal soft tissue profile discrepancy, a decrease in soft tissue profile convexity and a decrease in the prominence of point a relative to the facial plane.

The correlations between the changes in li-NPg and the measurements relating

Table 10.8. Correlations between the changes found in dento-skeletal and soft tissue profile measurements between the initial and final examination.

Significance level: $n=28$, $r \geq 0.375$, $P \leq 0.05$, $r \geq 0.478$, $P \leq 0.01$.

Variable	na.no.pg	na.a.pg	a.n.b.	Pg.N.no	Pg.N.a	Pg.N.ls	Pg.N.li	Pg.N.b	Pg.N.pg
S.N.A	0.051	-0.288	-0.132	0.055	0.271	0.200	0.204	0.168	0.244
S.N.B	0.145	0.153	0.230	-0.213	-0.080	-0.115	0.192	0.197	0.410
A.N.B	0.097	-0.527	0.418	0.302	0.425	0.374	0.042	-0.009	-0.151
S.N.Pg	-0.151	0.147	0.157	-0.282	-0.167	-0.224	0.049	-0.030	0.364
N.A.Pg	-0.091	0.099	0.125	-0.117	-0.102	-0.203	-0.095	0.186	0.155
li-NPg	-0.357	-0.381	-0.269	0.501	0.477	0.478	0.452	0.389	-0.020
ls-NPg	-0.151	-0.570	0.403	0.324	0.633	0.672	0.446	0.357	-0.083
overbite	-0.242	-0.226	-0.140	0.154	0.278	0.162	0.576	0.291	0.501
MR3-1	-0.171	-0.031	-0.004	0.328	0.066	0.128	0.141	0.131	-0.367
Ar3-1.MPI	0.226	-0.004	-0.025	-0.048	0.095	0.092	-0.058	-0.072	-0.101

Table 10.9. Correlations between mandibular rotation (MR 3-1), direction of condylar growth (Ar 3-1. RPI) and dento-skeletal changes between initial and final examinations.

Significance level: $n=20$, $r \geq 0.444$, $P \leq 0.05$; $r \geq 0.561$, $P \leq 0.01$.

Variable	n	SNA	SNB	ANB	SNPg	NAPg	li-NPg	ls-NPg
MR3-1	20	0.628	0.785	0.205	0.886	0.079	-0.526	-0.322
Ar3-1.MPI	20	0.111	-0.091	-0.234	0.129	-0.149	0.114	0.109

the soft tissue profile to the facial plane were found to be significant (except the correlation between li-NPg and Pg.N.Pg). The correlations between ls-NPg and Pg.N.a, Pg.N.ls, Pg.N.li, na.a.pg and a.n.b. were found to be significant. These correlations indicate that a decrease in the distance of the incisal edges to the facial plane is associated with a decrease in the prominence of the lips relative to the facial plane. Further a decrease in the distance of the incisal edges to the facial plane is associated with a decrease in the convexity of the soft tissue profile and the sagittal soft tissue profile discrepancy.

Changes in overbite were correlated with Pg.N.li and Pg.N.pg. The correlations indicate that a decrease in overbite is associated with a decrease in the prominence of the lower lip.

The relationship of condylar growth direction (Ar3-1.MP) and mandibular rotation (MR), to the changes in profile were examined and were found to be not significant. (Table 10.9).

Correlations between mandibular rotation and the changes in S.N.A, S.N.B, S.N.Pg and li-PgN were found to be significant. (Table 10.9). The correlations

Table 10.10. Correlations between dental and skeletal measurements and soft tissue measurements at examination 3.

Significance level; $n=28$, $r \geq 0.375$, $P \leq 0.05$, $r \geq 0.478$, $P \leq 0.01$.

Variable	na.no.pg	na.a.pg	a.n.b.	Pg.N.no	Pg.N.a	Pg.N.ls	Pg.N.li	Pg.N.b	Pg.N.pg
S.N.A.	-0.081	0.470	0.359	0.171	0.464	0.420	0.493	0.360	0.078
S.N.B	0.188	-0.132	0.049	-0.113	0.066	0.066	0.178	0.154	-0.147
A.N.B	-0.480	-0.608	0.558	0.509	0.715	0.635	0.567	0.551	0.402
S.N.Pg	0.291	0.065	0.085	-0.243	-0.168	-0.170	-0.081	-0.194	-0.286
N.A.Pg	-0.077	0.139	0.042	-0.051	-0.210	-0.268	-0.308	-0.306	-0.168
li-NPg	-0.456	-0.788	-0.567	0.529	0.873	0.877	0.876	0.806	0.338
ls-NPg	-0.467	-0.709	-0.584	0.616	0.870	0.847	0.869	0.759	0.451
overbite	-0.164	-0.238	0.334	0.072	0.181	0.157	0.254	-0.045	0.050

indicate that a forward rotation is associated with a decrease in the angles S.N.Pg, A.N.B; and S.N.A and a decrease in the distance li-NPg.

The correlation coefficients calculated between the measurements at the final examination (Table 10.10) indicate a significant relationship between the angle A.N.B and the soft tissue measurements. A large A.N.B angle tends to be associated with more prominent soft tissue structures relative to the facial plane and a more convex soft tissue profile. A similar relationship was found between li-NPg and ls-NPg and the soft tissue measurements. S.N.B, S.N.Pg and N.N.Pg were not found to be related to the soft tissue measurements and S.N.A. was found to be associated with the position of the upper and lower lips.

10.4 Discussion

Patients with aesthetically poor soft tissue profiles at the start of treatment (Group PC) were generally characterised by a convex skeletal profile (N.A.Pg), a concomitant large sagittal jaw discrepancy (A.N.B) and the incisal edges were more anteriorly positioned relative to the facial plane. The soft tissue profile reflects the underlying skeletal profile and position of the teeth by the facial convexity (na.a.pg) and the prominence of the lips. The nose was found to be more prominent in relation to the face (na.no.pg, Pg.N.no) in this group, and when viewing the profile the prominence of the nose is exaggerated by the retrognathic appearance of the chin. Cox and van der Linden (1971) studied the facial profiles of 72 subjects aged 18 years, which had been divided into four equal groups comprising the best and poorest profiles of both sexes. They found that in subjects with poorest profiles a larger convexity of both soft tissue and skeletal profiles was due to a more anterior positioning of dental, skeletal and soft tissue structures of the middle facial region. The comparisons in the present study lead to similar findings.

During the examination period the greatest decrease in skeletal convexity and sagittal jaw discrepancy was found in Group PC (the group with the poorest initial profile). The proportional relationship of the nose to the face remained the same during the examination period however the prominence of the nose in Group PC is accentuated relative to the upper lip, as the upper lip tends to become less prominent (a finding applicable to all groups). The changes in the soft tissue profile were not found to be significantly different for any group.

It was found that the change in the position of the incisal edges were related to the largest number of changes in the soft tissue profile. A decrease in the prominence of the incisors resulting in a decrease in the prominence of the soft tissue profile relative to the facial plane. In addition, a decrease in overbite was found to result a decrease in the prominence of the lower lip (li) and chin (pg). The changes in S.N.A, S.N.B, S.N.Pg, A.N.B and N.A.Pg were generally not found to be associated with changes in the soft tissue profile. Therefore, it may be concluded that the change observed in the soft tissue profile are primarily associated with the changes in the position of the incisors.

The lips and denture became less prominent in relationship to the face in the course of its maturation (Subtelny 1959, Enlow 1968). The findings of the present investigation illustrate a similar process and it is of interest that although the effects of treatment are superimposed on the developmental processes, the changes of the soft tissue profile in all three groups with different profile characteristics at the initial examination were not found to be different during the examination period.

The inspection of the profiles at the final examination shows that characteristics described at the start of treatment are readily discernable, with the exception of the vertical lip relation which was generally found to be a closed vertical lip relation at rest. Furthermore, profiles in each group were characteristic of that group only. The differences in profiles between the three groups were similar to those found at the initial examination.

The measures of the soft tissue profile at the final examination were found to be related almost exclusively to the angle A.N.B and the position of the mandibular and maxillary incisors relative to the facial plane (Is-NPg, li-NPg). The other values expressing the relationship of points A, B and Pg to the sella nasion plane and the skeletal convexity (N.A.Pg) have in only a few instance a relation to the soft tissue profile. These findings indicate that the sagittal jaw discrepancy is an important factor in determining the position of the incisors in the face and that these factors influence the soft tissue profile.

In conclusion: changes in the soft tissue profile were due primarily to changes in the position of the incisors. Furthermore, the mean changes in the soft tissue profile were similar in the three groups. These changes result in a decrease in the prominence of the lips which in some situations may cause an apparent increase in

the prominence of the nose. Finally, there is no evidence of a characteristic soft tissue profile resulting after treatment, rather, profiles maintain the characteristics which were initially found.

status of dentition and periodontium

11.1 Introduction

Unfavorable side effects of orthodontic treatment have been reported in many publications. They include damage to the periodontium (Sjolién and Zachrisson 1973 and Zachrisson and Alneas 1973, 1974) and root resorption (Reitan 1969). These studies indicated the necessity to evaluate our own material to determine the incidence of root resorption and periodontal pocketing. Moreover, it was felt that: a posttreatment study of the results of orthodontic treatment would be inadequate without an evaluation of the status of dentition and periodontium; this evaluation would indicate if it is necessary to pursue further investigations on a broader basis.

This aspect of the investigation was to evaluate the incidence of periodontal pocketing, changes in the height of the anterior alveolar crest, root resorption and positions of the third molars at the final examination. The depth of the gingival sulcus was measured using a graduated periodontal probe and the height of the anterior alveolar crest was measured on lateral cephalometric radiographs. For technical reasons root resorptions were not quantitatively examined and this evaluation was performed by inspection of the radiographs. The position of the third molars was examined in a similar way.

11.2 Sulcus depth determination

11.2.1 Material

The sample comprised 24 subjects. This sample differs in composition from the sample used for the cephalometric and dental cast analysis. Fifteen cases were of the original sample and nine were additional cases. The sample differs as it was not

possible for all subjects of the original sample to return for this investigation. The determination of the sulcus depth was performed an average of 57.8 months (standard deviation 24.3 months) after the removal of the fixed appliance. Bite wings, an orthopantomograph and intraoral slides were made at the time of the investigation.

It was not possible to obtain a control group due to the difficulty in finding a sample similar in all respects except that of treatment. A longitudinal study was also not possible as no usable data was available of the periodontal condition as, this aspect was not extensively investigated at the start of treatment. Despite these disadvantages of our material this evaluation was undertaken for the reasons previously mentioned.

11.2.2 Method

To measure the depth of the gingival sulcus a periodontal probe graduated in mm was used. The measurements were made from the bottom of the gingival sulcus to the gingival margin. The distance was measured to the nearest mm and recorded on a standardized score sheet by an assistant. Interproximal, buccal and lingual measurements were taken of the sulci of all teeth except the distal interproximal sulcus of the second molars and the sulci of the erupted third molars. The interproximal measurements were all taken from the buccal or labial aspects of the teeth, as close to the contact points as possible and an attempt was made to measure parallel to the roots of the teeth. A periodontal pocket was diagnosed when the sulcus depth was greater than three mm.

11.2.2 Error of the method

To assess the reproducibility of the sulcus depth measurements 10 subjects were examined on two separate occasions, at least one hour apart. The results of the double determinations are shown in Figure 11.1. Fourhundred and forty double determinations were made of interproximal sulci. The greater majority of the double determinations were the same, a number differed by 1 mm and two differed by 2 mm.

Coppes (1972) studied the reliability of sulcus depth determinations and found the clinical measurement of pocket depth to be reasonably accurate. The results of the double determinations of the present study would appear to lead to similar conclusions.

11.2.4 Results

An inspection of the score sheets showed that in a few cases labial or lingual pockets were present in the lower incisor segment. In the buccal segments of the dental arches few buccal or lingual pockets were observed. In view of the small

	-2	-1	0	+1	+2	
1			4			4
2		6	98	27		13*
3		44	212	12	1	269
4		9	12	3		24
5		2	8			10
6		1				1
7	1					1
Total	1	62	343	42	1	440

Figure 11.1. Difference between first and second determinations of sulcus depth to determine error of the method.

numbers involved a statistical analysis of the measurements of these surfaces was not made.

The results of the sulcus depth determinations of the interproximal measurements are shown in Table 11.1 and the mean differences between different surfaces are given in Table 11.2. The results of the measurements are illustrated in Figure 11.2. It is evident from the examination of tables and figure that the mean sulcus depth progressively increases the further distally the measurements were taken. The range of individual values also indicates that the largest pocket depths are found in the maxillary arch. In the buccal segments of the mandibular arch the largest individual values are slightly less than in the maxillary arch. The mean sulcus depth is less in the mandibular molar region than in the maxillary molar region. In the buccal regions the mean of the sulcus depth of the distal surface are significantly greater than that of the mesial surface in a number of situations. Also the sulcus depths of the distal surfaces of the buccal teeth were often found significantly deeper than the distal surfaces of the more mesial teeth. The largest mean sulcus depth was 4.38 mm with a standard deviation of 1.28 mm and range from 3 to 7 mm. This was the depth distal to the maxillary left first molar. On the right side the largest mean depth was 3.4 mm, with a standard deviation of 0.93 mm and a range from 2 to 5 mm. This was found on the mesial surface of the first molar. The smallest mean values were found on the interproximal surfaces of the mandibular incisors.

Figure 11.3 shows the distribution of pockets in individual patients. Sixteen cases were found to have from 0 to 6 pockets. Six had from 8 to 12 pockets and two cases had a total of 18 and 20 pockets respectively.

Figure 11.3. Frequency of Periodontal Pockets in individual Subjects.

Figure 11.2. Measurements of sulcus depth for individual surfaces. Mean — ± 2 S.D. - - - - -

Table 11.1. Mean values and distribution of the individual values of the sulcus depth measurements. Measurements in mm.

Maxillary dental arch					Mandibular dental arch				
Variable	Mean	S.D.	range		Variable	Mean	S.D.	range	
17m	3.29	0.91	1	5	37m	3.00	0.51	2	4
16d	3.42	0.93	2	5	36d	3.17	0.48	2	4
16m	3.13	0.80	2	5	36m	3.00	0.51	2	5
15d	3.08	0.65	2	5	35d	2.83	0.48	2	4
15m	2.88	0.61	2	4	35m	2.88	0.34	2	3
13d	2.67	0.48	2	3	33d	2.88	0.34	2	3
13m	2.71	0.46	2	3	33m	2.75	0.53	2	4
12d	2.46	0.72	1	4	32d	2.67	0.48	2	3
12m	2.38	0.58	2	4	32m	2.54	0.59	2	4
11d	2.42	0.58	2	4	31d	2.42	0.65	1	4
11m	2.42	0.72	1	4	31m	2.38	0.49	2	3
21m	2.29	0.62	1	3	41m	2.33	0.56	1	3
21d	2.29	0.55	1	3	41d	2.63	0.58	2	4
22m	2.29	0.75	1	4	42m	2.50	0.51	2	3
22d	2.42	0.65	1	4	42d	2.83	0.38	2	3
23m	2.58	0.88	1	4	43m	2.79	0.72	2	5
23d	2.67	0.56	2	5	43d	2.79	0.51	2	4
25m	3.21	0.93	2	5	45m	2.75	0.61	2	4
25d	3.21	0.72	2	5	45d	2.75	0.53	2	4
26m	3.54	0.98	2	5	46m	3.21	0.41	3	4
26d	4.08	0.88	3	5	46d	3.21	0.59	2	4
27m	4.38	1.28	3	7	47m	3.25	0.53	2	4

m and d refer to the mesial or distal surface on the tooth.

Oral hygiene. An objective determination of plaque and oral debris in a select sample such as the present one is not possible. However, a subjective estimation of the general oral hygiene was made using the intraoral colour slides. Attention was paid to redness and swelling of the gingiva, the presence of debris, plaque and calculus. The oral hygiene was estimated as good, average or poor. It was observed in the two subjects with the largest number of pockets that they also had poor oral hygiene. In subjects with good oral hygiene the number of pockets was small.

Table 11.2. Mean differences and their standard deviations of the different interproximal surfaces compared.

Significance level; $n=24$, $t \geq 2.069$, $P < 0.05$, $t \geq 2.807$, $P < 0.01$.

Variables	Mean	S.D.	t-test	Sign
16m-16d	0.29	0.45	3.222	$P < 0.01$
15m-15d	0.21	0.41	2.625	$P < 0.05$
13m-13d	0.04	0.20	1.000	NS
23m-23d	0.08	0.50	0.800	NS
25m-25d	0.00	0.42	0.000	NS
26m-26d	0.54	0.51	5.400	$P < 0.01$
36m-36d	0.17	0.48	1.700	NS
35m-35d	0.04	0.36	0.571	NS
33m-33d	0.13	0.68	0.928	NS
43m-43d	0.00	0.42	0.000	NS
45m-45d	0.00	0.29	0.000	NS
46m-46d	0.00	0.83	0.000	NS
15d-16d	0.33	0.48	3.300	$P < 0.01$
25d-26d	-0.88	0.61	6.769	$P < 0.01$
35d-36d	0.33	0.48	3.300	$P < 0.01$
45d-46d	-0.46	0.51	4.600	$P < 0.01$
16d-46d	-0.21	0.51	2.100	$P < 0.05$
26d-36d	0.92	0.72	6.133	$P < 0.01$

11.3 Anterior alveolar crest height

The sample consisted of the 30 subjects used for the general cephalometric and dental cast investigation. The measurements were made at the three stages of the investigation.

11.3.1 Measurements

Is-Pr The distance from the incisal edge of the most anterior maxillary incisor (Is) to the most anterior superior point of the alveolar process of the maxilla (Pr).

Ii-Id The distance from the incisal edge of the most anterior mandibular incisors (Ii) to the most anterior superior point of the alveolar process of the mandible (Id).

11.3.2 Results

The differences were calculated between the successive examinations (2-1, 3-2

and 3-1). The mean changes for both maxillary and mandibular arches were not found to be significant.

To evaluate the relationship of individual changes to changes in overjet and overbite and several other parameters during and following treatment a number of correlations were calculated which were not found to be significant.

11.4 Root resorption

As no standardized radiographs were available which were suitable for examining decreases in root length, only a rough estimate of root resorption is possible. By inspection of the orthopantomographs and intraoral radiographs of the final examination and by a comparison with the radiographs of the initial examination an evaluation of the incidence of root resorption was made of the sample used for the sulcus depth determinations.

In a number of cases slight resorptions were seen of different roots. No extensive root resorption was evident in these cases. In only one case were marked root resorptions identified. In this case shortening of the mesial and distal roots of the lower first molars was observed. The distal roots were also somewhat shorter than the mesial roots. The root apices of the mandibular incisors appeared blunted and apparently shortened. A similar finding was evident for the maxillary incisors. The roots of the maxillary molars also appear shortened.

11.5 Mandibular third molars

Position of the mandibular third molars was evaluated by inspection of the final radiographs. In 17 out of 24 cases examined the molars appear to be erupting normally or were vertically positioned, level with the second molars. In one case the mandibular molars were impacted horizontally and in another case this was found on one side only. In one case a unilateral mesio-horizontal impaction was observed on the other side the molars was absent. In two cases mesio-horizontal impactions were bilateral. In the remaining two cases molars were bilaterally absent in one instance and unilaterally in another.

11.6 Discussion

The statistical analysis of the sulcus depth determinations showed that the mean sulcus depth increased significantly the further distally the measurements were taken and the mean sulcus depth appears greater in the maxillary dental arch than the mandibular dental arch. The largest periodontal pockets which were found were

also in the maxillary arch in the region of molars and premolars. Furthermore the largest number of pockets were present in individuals with poor oral hygiene.

Coppes (1972) investigated differences in sulcus depth in non treated subjects. He found a tendency for the sulcus depth to increase the further distally the measurements were taken. Our results appear similar.

Sjolien and Zachrisson (1973) estimated the amount of periodontal bone support in orthodontically treated subjects two years after treatment. They studied 59 subjects treated with an Edgewise type appliance and the extraction of four first premolars. These subjects were compared with a control group. They found that periodontal bone support was less distally than mesially, and that there was less bone support in orthodontically treated cases, particularly in the maxillary anterior region and in the extraction spaces. They suggested that the loss of bone support was partially due to loss of marginal alveolar bone.

Zachrisson and Alneas (1973) found in subjects, two years after treatment, a loss of gingival attachment in the buccal aspects of maxillary teeth greater than that of the control group. Although, no difference in pocket depth or clinical crown height was found between the two groups examined. Further, these authors found no relationship between loss of gingival attachment and changes in overjet and other factors examined. Our findings were also similar when changes in alveolar crest height were investigated in relation to changes in the dental arches. Zachrisson and Alneas (1974) examined in a similar group of subjects the distance from the cemento-enamel junction to the alveolar crest. They found a significant mean difference between the treated and control group. The loss of alveolar bone was greater in orthodontically treated subjects. In addition the pressure side of the extraction spaces showed the greatest difference. They concluded that although, orthodontically treated subjects had a greater bone loss than the control group, the differences were small. However, they stressed that this difference may be of clinical significance, because the retentive apparatus of the tooth is largely restricted to the coronal two thirds of the root.

The studies referred to above indicate that orthodontic treatment appears to be associated with an adverse effect on the periodontium, however, the clinical significance will probably only be evaluated after a longer period. Duterloo (1974) has observed that on lateral cephalometric radiographs in specific cases treated with the Begg technique a change in the cortical plate lingual to the maxillary and mandibular incisors occurs. It diminishes during treatment and is not observable in the period subsequent to treatment. The clinical implications are not clear. It was thought that tooth movements are concomitant with intensive bone remodelling and the formation of bone with a low density.

The relationship of poor oral hygiene to the incidence of periodontal pocketing is evident in our material. This relationship has been found by Sheiham (1969a,

1969b,) in non treated subjects. He found a strong relationship between poor oral hygiene, advancing age and the incidence of periodontal pockets.

Root resorption was found to be extensive in one case only. In several other cases slight resorptions were found. Our evaluation was limited by the lack of standardised radiographs. These are necessary for a quantative analysis.

The data from our own study permit only limited conclusions. However, the findings indicate that a systematic longitudinal investigation of the relationship of orthodontic treatment and the status of the periodontal tissues is necessary.

general discussion

This general discussion is intended to coordinate the findings and to expand on a number of general observations pertaining to this study.

Simons and Joondeph (1973) and Shapiro (1974), studied cases ten years after retention in the belief that this is an adequate period after which posttreatment results can be evaluated. Although in the present study and that of Dermaut (1974), the posttreatment periods were shorter, the results are similar to those of the above mentioned authors. Furthermore, Huggins and Birch (1964), found that relapse of retracted maxillary incisors was most rapid within the first six months after retraction. Similarly, the experimental findings of Reitan (1967) indicate that relapse of orthodontic tooth movement is rapid immediately after removal of the appliance in tipping, rotating and bodily movements. It thus appears that an evaluation of general trends of changes in the posttreatment period can be made at a relatively early stage of this period, although this does not diminish the value of a long term study.

Correlation coefficients were calculated between posttreatment changes of a number of variables and the posttreatment duration. These were all found to be not significant. The general inability to show a relationship between posttreatment changes and posttreatment duration is a further indication that the most substantial changes in the posttreatment period occur at an early stage.

A limitation of our study as well as those of Simons and Joondeph (1973), Shapiro (1974) and others reviewed is the lack of an intensive systematic longitudinal posttreatment study. It is suggested that posttreatment changes be studied at bimonthly intervals during the early postretention period. This type of study would provide further insight into the duration and intensity of posttreatment changes.

A factor which can be most adequately evaluated over a long period is that of the influence of orthodontic treatment on the periodontium. As suggested by Zachrisson and Alneas (1974), a small decrease in the height of the alveolar crest may be of great clinical significance. The relationship of orthodontic treatment to maturation changes in the periodontium is not clear. Our findings in this respect also indicate the need for further investigation.

The finding that in the present investigation subjects with different malocclusions may have similar skeletal and soft tissue profiles is evidence of the inadequacy of a classification based on dental characteristics for the purpose of comparing changes in different groups during and following orthodontic treatment. It is apparent from our profile study that a classification system should be used which evaluates both dental and skeletal characteristics to reduce individual variability within the groups to be compared. Our method of selecting different groups by the similarity of the profile possibly resulted in finding significant differences of skeletal changes between the three groups compared. This is in contrast to the findings of de Laat (1974), who reported no skeletal differences in 50 Begg cases classified as Class I or Class II malocclusions and compared on this basis. The difference in results of the two studies is probably due to the difference in the method of analysis.

An aspect of the changes in the posttreatment period, are those changes which occur in the retention period. These were not examined, as the primary interest was an evaluation of treatment results over a longer period and because it is clear that the situation at the end of treatment can be largely maintained as long as retention procedures are continued. Nevertheless, some remarks on the retention period in relation to posttreatment changes can be made. Despite similar treatment and retention procedures, different types and amounts of posttreatment change were observed due presumably to biological factors which influence the effects of treatment, or the incompatibility of treatment changes with the oral environment. It seems that long term retention is unlikely to offer additional stability but rather postpones the posttreatment changes. It is suggested that short term retention procedures are generally preferable.

Although relapse was found in a number of situations it is obvious that it is usually limited and that substantial improvements of the occlusion, oral health and general aesthetic appearance of dentition and face were attained. An "ideal" occlusion was strived for but there are numerous influencing factors which supervene on the changes due to treatment and cause various posttreatment changes. We were not able to compare our results with a relevant group of cases treated with other techniques; nevertheless results of studies reported in the literature suggest that the final average results are similar irrespective of the technique employed.

Overbite (vertical) tended to increase in the posttreatment period and it was observed that a large initial overbite tended to be large at the final examination. However, it is important to note that there were also individual cases with a large initial overbite in which a large decrease of overbite during treatment was relatively stable in the posttreatment period. A number of factors in the posttreatment period were identified which were related to an overbite increase in the posttreatment period: a forward rotation of the occlusal plane sometimes accompanied by a molar intrusion; an increase in overjet; a retroclination of mandibular incisors; and an increase in interincisal angulation. These factors enumerated are all dental in nature and closely related by their physical proximity. It seems unlikely that their contribution to overbite instability is substantial. Probably the most important factor identified is that of the direction of condylar growth. A vertical direction of condylar growth was shown to be related to overbite relapse while a sagittal direction of condylar growth was associated with overbite stability. Although overbite relapse was greatest when a vertical direction of condylar growth was observed, this factor should not necessarily be a contraindication for the treatment of a deep overbite. Rather, a different timing of treatment may be indicated as advocated by Björk (1969). He suggests that a stabilising appliance, such as a bite plane, introduced before puberty will prevent the type of deep overbite developing which is found with vertical condylar growth and a forward rotation of the mandible.

Overjet in the posttreatment period was largely stable although in a few cases some relapse was found to occur. The following factors were found to be associated with an overjet relapse: an increase in overbite; an increase in the interincisal angle and a retroclination of proclined mandibular incisors. The most important factor would seem to be the retroclination of a proclined incisor, as it appears to bear a direct causal relationship to the relapse of overjet. This factor was also found to be related to a decrease in mandibular arch circumference and hence an increase in crowding. De Laat (1974) studied the changes occurring when different techniques are used. He found that lower incisor retraction in the treatment period was greater in subjects treated with the Tweed technique than with the Riedel or Begg technique. One factor responsible for this phenomenon may be the amount and direction of forces used during treatment. However, it may also be due to a difference in severity of malocclusions: severe malocclusions are likely to have a greater proclination of lower incisors. A change in inclination of the maxillary incisors in the posttreatment period was not observed to be associated with overjet relapse. An interesting finding is the absence of an observable relationship between posttreatment changes in mandibular rotation and overjet. In fact no statistical relationship was found between mandibular rotation in the posttreatment period and changes within the dental arches.

Increases in the anterior dental arch circumference in the treatment period tended to be unstable in the posttreatment period and decreases occur which result in reappearance of crowding. These changes were closely associated with those of intercanine width. However, it is noteworthy that despite a net mean increase in mandibular intercanine width in cases with a sagittal direction of condylar growth, a similar relationship was not observed between the anterior dental arch circumference and condylar growth. It is important to note that in some cases substantial net decreases in crowding occurred while in other cases crowding remained unchanged or increased. From the findings of the present investigation and the opinions expressed in the literature, it is clear that the reasons for the reappearance of crowding or the stability of arch circumference is a complex problem. Several factors have been identified although their relative importance in individual cases is unclear.

summary

The purpose of the investigation described in this thesis was to study in retrospect a number of changes of the dentition, its occlusion and the facial skeleton which occurred in the treatment and posttreatment periods in a sample of 30 cases treated with the Begg fixed appliance techniques. Seventeen of these cases had malocclusions which were classified as Class II division 1, six as borderline and seven as Class 1.

The second chapter deals with the material and the methods of investigation. Dental casts and lateral cephalometric radiographs were used which recorded the status of the subjects at the start of treatment (initial examination), at the removal of the fixed appliance and the result at least one year after retention procedures had ended (final examination). A detailed account was given of the methods and errors of the methods of measuring on dental casts and lateral cephalometric radiographs. This includes an account of the Björk structural method of superimposing mandibles.

In Chapter 3 changes in overbite are described. It was found that overbite tended to be the same at the initial and final examinations. However, subjects with a large initial overbite tended to have a greater net decrease in overbite than those subjects with a small initial overbite. Moreover, in some subjects with a large initial overbite a considerable net decrease occurred and in others the net change was minimal.

The vertical changes in the positions of the incisors and the change in inclination of the occlusal plane are examined in chapter 4. The changes in inclination of the occlusal plane were examined using the Björk structural method of superimposition. Furthermore these changes were examined in relation to overbite. During the period of treatment mandibular incisors were either intruded, remained vertically stable or erupted. Intrusion was related to a large decrease in overbite in

this period. In the posttreatment period incisors generally erupted. These posttreatment changes were not found to be related to posttreatment changes in overbite. Mandibular molars appeared to erupt or were extruded during treatment and were intruded or erupted further in the posttreatment period. The extent of the overbite decrease during treatment was related to the extent of incisor intrusion, molar extrusion and a consequent backward rotation of the occlusal plane. The occlusal plane was observed to rotate backward in 18 cases during treatment and forward in 12 of these cases in the posttreatment period. A number of cases were also found in which the rotation was either backward or forward throughout the period of investigation. A forward rotation of the occlusal plane in the posttreatment period was related to an increase in overbite. Backward rotation during the treatment period was due to a greater occlusal positioning of mandibular molars than mandibular incisors while in the posttreatment period a forward rotation was due to a greater occlusal positioning of incisors relative to the mandibular molars. Maxillary incisors generally erupted during and following treatment. These changes were not shown to be associated with changes in overbite.

The changes in overjet are described in Chapter 5. Irrespective of the size of the initial overjet a large amount of stability was found in the posttreatment period. In a few cases with a large initial overjet some relapse occurred although never to the extent of the reduction during treatment. Changes in overjet were found to be related to those of overbite.

In Chapter 6 the sagittal inclination of maxillary and mandibular incisors are discussed. The interrelationship of these changes were examined as well as their relationship to changes in overbite and overjet. Changes in inclination of mandibular incisors during treatment were generally not found to be stable in the posttreatment period. This, in contrast to changes in inclination of the maxillary incisors which were quite stable and tended to procline only slightly in the posttreatment period. Mandibular incisors which were retroclined at the initial examination in Class II division I cases and which were proclined during treatment were found to be stable. Similarly, proclined mandibular incisors in Class I cases which were retroclined in the treatment period were also stable. Retroclination of mandibular incisors in the posttreatment period were related to increases in overjet and overbite in this period. Posttreatment increases in the interincisal angle were also related to increases in overbite and overjet although posttreatment changes in inclination of the maxillary incisors were not.

Chapter 7 deals with intercanine width and anterior dental arch circumference of maxillary and mandibular dental arches. An increase in dental arch circumference is analogous to a decrease in crowding of incisors and canines. The dimensions of all four variables examined were generally found to increase in the treatment period and to decrease in the posttreatment period. These changes were related.

No net change in mandibular intercanine width was found. However, significant mean net increase of the maxillary intercanine width, the mandibular anterior dental arch circumference and the maxillary anterior dental arch circumference were found. The net mean increases in arch circumference indicate net mean decreases in crowding. Furthermore, changes in individual cases were highly variable. In some cases a substantial net increase occurred and in others a net decrease. A factor found to be related to a decrease in mandibular arch circumference in the posttreatment period was a retroclination of mandibular incisors in this period.

Using the Björk structural method of superimposing mandibles the direction of condylar growth, the change in inclination of the mandibular plane as well as mandibular rotation were examined.

In Chapter 8 the direction of condylar growth and change in inclination of the mandibular plane are examined. Thereafter, the direction of condylar growth was examined in relation to vertical changes in the dental arches, the overbite and the dental arch dimensions. The sample was divided into two groups on the basis of the direction of condylar growth (vertical or sagittal) and further subdivided into four subgroups on the basis of a large or small overbite. This aspect of the study revealed that the treatment of a large initial overbite was successful when the direction of condylar growth was sagittal. A relapse of a large initial overbite occurred when the direction of condylar growth was vertical. No differences in the changes in occlusal plane inclination or the vertical positions of the incisors were found when a deep overbite with a vertical or sagittal direction of condylar growth was treated. A greater increase in mandibular intercanine width was observed when the direction of condylar growth was sagittal, but, this was not observed for the mandibular dental arch circumference. Changes in mandibular plane inclination were found to be related to those of overbite.

The analysis of mandibular rotation in Chapter 9 showed that a backward rotation frequently took place in the treatment period. However, no individual factor was shown to be of influence. In the posttreatment period a forward rotation occurred in all cases except one. This, was not found to be related to changes in overbite, overjet or any other variables examined. The total mandibular rotation was found to differ between subjects with a sagittal or vertical direction of condylar growth: the forward rotation of the mandible was significantly greater in subjects with a vertical direction of condylar growth.

The facial profile is discussed in Chapter 10. The sample was divided into three groups by an inspection of profile photographs. The profiles of the three groups were compared subjectively and using cephalometric measurements. At the start of treatment the group with the poorest facial appearance had the most prominent middle facial structures in relation to the facial plane. Between the initial and final

examination the sagittal jaw discrepancy decreased by the greatest amount in this group. Additionally, this group had the greatest decrease in skeletal convexity. Sagittal changes in incisor position were similar for all three groups and no significant differences were shown in the changes of the soft tissue profile. In all three groups the lips became less prominent in relation to the face. At the final examination the differences found between the three groups at the start of treatment were still present.

In Chapter 11 an evaluation of the status of the dentition and periodontal tissue at the final examination is given. A small number of periodontal pockets were found in the majority of subjects. However, in two subjects with poor oral hygiene a large number of pockets were found. Root resorptions were found to a small degree in a number of patients. In only one case were the resorptions marked and widespread. In two cases horizontally impacted mandibular molars were found and in two other cases mandibular molars were mesio-horizontally impacted. In the remaining cases they were erupting or positioned normally.

In the general discussion, Chapter 12, a number of observations pertinent to the investigation are made and the findings of the previous chapters coordinated. A number of suggestions for subsequent longitudinal studies are made. The results of treatment are discussed and a number of factors enumerated which were found to be associated with stability or relapse of the results attained at the end of treatment.

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