

UNIVERSITY OF EDINBURGH.

MESIO-OCCLUSION, A CLINICAL AND ROENTGENOGRAPHIC
CEPHALOMETRIC STUDY.

Thesis

Presented for the Degree of Doctor of Philosophy.

by

Geoffrey Buxton Hopkin, HD.D., D.D.O., L.D.S..

MAY 1961.



ACKNOWLEDGEMENTS.

I wish to acknowledge my indebtedness to Professor J. Boyes and Professor G. J. Romanes for much valuable advice and criticism. I also wish to acknowledge the advice and encouragement received from the late Professor J. C. Brash and from Professor Emeritus A. C. W. Hutchinson under whose supervision this study was started.

I wish to thank my colleagues past and present in the Orthodontic Department for their kindness in referring patients of interest to me.

I wish also to thank Miss E. A. Mason and Mr. D. A. Dixon and Mr. G. A. James for proof reading and for so willingly carrying out the extra duties which fell to them as a result of my undertaking this study.

My thanks are due to Mr. A. R. Bradshaw for advice on radiology, Dr. J. N. Mansbridge for statistical advice and facilities and to Mr. V. Smith for bibliographic aid.

I wish to thank Miss Olive Lees for invaluable secretarial assistance and the following for their technical services:- Miss M. Benstead for the histo-grams and aid with diagrams, Mrs. T. Harris for radiographic assistance, Mr. W. Duncan for much help with records and illustrations and Messers. A. Hunter, R. Renton and A. Standon for their photographic work.

Table of Contents.

	<u>Page No.</u>
Introduction and statement of aims.	1
Review of the literature.	4
Summary of review of the literature.	17
Material	22
The roentgenographic method employed.	30
Definitions of points and planes employed as basis for linear and angular measurements.	31
Discussion of points and planes.	35
Linear and angular measurements.	38
Discussion of linear and angular measurements.	43
Errors of the Method.	
1. Arising from the radiographic technique.	47
2. In the determination of cephalo- metric landmarks.	50
3. Errors of measurement.	53
Methods of superimposition of serial tracings.	56
<u>Part I.</u>	
A comparative roentgenographic cephalo- metric analysis of 226 cases of mesio- occlusion (Class <u>III</u>) and 157 cases of Neutro-occlusion.	
Introduction and outline of investigations.	62
I Comparison of Class <u>III</u> and Neutro- occlusion mean facial diagrams.	68
II Comparison of Class <u>III</u> and Neutro- occlusion mean linear and angular measurements.	70
Comparison of means: conclusions.	97

Part I contd.

	<u>Page No.</u>
III "Differential Analysis" of Class <u>III</u> material.	99
Summary and conclusions of "Differential Analysis."	116
IV Analysis of linear and angular measurements in individual cases.	120
Summary and conclusions of individual analysis.	124
V Examination of mean measurements for growth changes.	126
Discussion of growth changes.	133
VI Examination of mean measurements for sex differences.	136

Part I.

Summary.	140
Findings and conclusions.	142
Final conclusions.	147

Part II.

Roentgenographic cephalometric analysis of treated cases of mesio-occlusion.	
Introduction and review of literature.	149
Material and methods of treatment.	151
Method of analysis.	152
<u>Findings.</u>	
Introduction.	155
I. Deciduous dentition cases	
A. Results of treatment.	
1. Correction of incisor relationships.	157

Part II contd.

	<u>Page No.</u>
(A. <u>Results of treatment contd.</u>)	
2. Results of Occipital traction.	159
B. Growth and developmental changes.	161
1. Development of permanent incisor occlusion.	162
2. Growth changes in the cranial base.	167
3. Growth changes in the mandible.	170
II Treatment and growth changes in the mixed and permanent dentition cases.	172
Angular changes in mixed dentition cases.	173
Angular changes in permanent dentition cases.	185
<u>Summary.</u>	
1. Changes following appliance treatment.	188
2. Growth changes.	190
III Comparison of treatment and growth changes in a series of relapsed cases with those in a series of successfully treated cases.	193
Comparison of mean net angular changes in stable and relapse cases.	199
Growth changes in stable cases.	202
Growth changes in relapse cases.	205
Summary and discussion.	211
Conclusions comparison of stable and relapse cases.	216
<u>Part II.</u>	
Summary	218
Conclusions	220
Final Conclusions	225
References.	226
	(1- V)

Introduction.

Mesio-occlusion is that condition of malocclusion of the teeth in which the lower molars occlude more mesially than normal with the upper molars. It constitutes Class III of Angle's Classification of Malocclusion and is the least common of the three classes.

The relative rarity of this condition may be the reason why so little attention has been given to the roentgenographic cephalometric study of the cranio-facial patterns associated with it. The published papers are few, whereas those dealing with the opposite condition, disto-occlusion, are many.

The main purpose of this study is to remedy, in some measure, this deficiency by making a roentgenographic cephalometric study of the cranio-facial structure, using lateral skull radiographs of patients with mesio-occlusion. In addition an opportunity is taken to analyse the changes in the cranio-facial structures during and after the Orthodontic treatment of mesio-occlusion. The publications on this aspect of mesio-occlusion when this study began in 1954 were a single paper and a few case reports.

The questions which were posed at the commencement of the study are as follows:-

1. Is there a specific cranio-facial pattern associated with mesio-occlusion? If not, are there various relationships and proportions of the

structures involved that can combine to produce a similar occlusal picture? If this is so, how do these proportions and relationships differ from those associated with neutro-occlusion?

2. Do the growth changes in cranio-facial pattern differ in mesio-occlusion from those that occur in neutro-occlusion?

3. Is there any evidence of sex differences in the cranio-facial pattern in mesio-occlusion?

4. What are the changes that are found after Orthodontic treatment, and to what extent are these changes the result of treatment or of growth?

5. What are the factors associated with the relapse of a corrected mesio-occlusion?

In the following pages, after a review of the relevant literature, the patients studied, and the methods employed are described and discussed.

The findings and conclusions of the thesis are presented in two parts.

In Part I, the first three questions posed above are investigated by means of a roentgenographic cephalometric analysis of 226 patients with mesio-occlusion and 157 patients with neutro-occlusion.

Part II is primarily concerned with the last two questions and consists of serial roentgenographic cephalometric analyses of the changes following Orthodontic treatment in 130 patients with mesio-occlusion. The findings of the serial studies are

also correlated with the findings in Part I regarding growth and development changes.

The statistical data is contained in the appendix which has been bound as a separate volume. Tables 4-25 relating to the text in Part I have been placed in the appendix because of their size and for ease of reference. The remaining tables, 26-38, are included with the text as are the illustrative figures 1-4 in the introduction. For ease of reference the rest of the figures 5-25 and the illustrative plates 1-31 of treated cases have been put in the appendix. The different sections of the appendix are indicated by index tabs and the tables 4-25, the figures 5-25 and the plates 1-31 have been given numbered tabs.

Review of Literature.

As has already been explained in the introduction, the decision to undertake this study was influenced in part by the lack of roentgenographic cephalometric studies of Class III malocclusions.

The papers on this subject published prior to the commencement of the study in 1954 are very few but, as will be seen, some papers have been published since. In addition it was thought worth-while to take into consideration several craniometric studies of Class III malocclusion which have been published. These use data gathered by measuring living subjects or skulls. Particularly valuable are those of De Coster (1927) (1929) and Hellman (1927) (1931) (1939). It is however to the earlier work in this field by Rushton (1911) that reference will be made at the outset. Rushton's paper is the earliest that has been found dealing with the measurement of jaw form and jaw relationships in malocclusions, as opposed to their subjective clinical assessment. His work deserves mention not only because he realised the necessity for measurement to provide standards for the comparison of the normal with the abnormal, but also because he foreshadows modern methods of assessment of jaw relationships based on roentgenographic cephalometric techniques. He made a large number of measurements on living subjects and skulls. Of interest to this study are his measurements of the

mandible and of his auriculo-facial or profile angle. Comparing the protruded mandible with the normal he found a larger mandibular angle both in adults and in children. The linear dimensions of the mandible did not differ from the normal greatly in either age group but Rushton himself stressed that his measurements could not be regarded as biometrically accurate. The other measurement of interest is the "auriculo-facial angle." This he formed by a line from nasion to the prominence of the chin (pogonion) and one from nasion to a point in front of the antihelix of the ear. (Approximates the tragon of De Coster and Hellman q.v.) This angle corresponds to the facial angle of Downs (1948). Rushton found the angle greater than normal in cases of protrusion and he noted that protrusion of the mandible, as judged by the profile angle, may exist without labial occlusion of the mandibular incisors (i.e. Class III occlusion). This assessment of the jaw relationships, independent of the occlusion, foreshadows the skeletal classification of Ballard (1948).

Nine years later Sicher and Krasa (1920) (1922) reported on their examination of 53 skulls whose occlusions were classed as :- normal 40, Angle Class II 6, and Angle Class III 7. They concluded that the reason for the different occlusions was related entirely to the size of the lower jaw. In the Class III group they noted an increase in the

measurement basion to nasion (Cranial Base Length.) Following the publication of the first paper by Sicher and Krasa, Grieve (1921) published a critical review of their work after re-examining the same skulls. Instead of an increase in the cranial base measurement, he found a decrease in the distance nasion to basion compared with the normal and he concluded that the Class III crania were partly "opisthognathic" (maxillary retrusion) and partly prognathic (mandibular protrusion). Shortly after Pfaff (1923) published his findings on an examination of 754 skulls of which 13 were Class III. Of these latter he said that while there was a slight recession of the maxilla the main difference was in the greater size of the mandible.

De Coster (1927) made measurements on living subjects. Using tragion as his base point, he made radial measurements to nasion, naso-spinale, prosthion, infradentale and gonion. He also measured the distance gnathion - gonion. He measured 1,500 adults and 200 children. He selected 304 adults as normal and divided the remainder into groups of cases of maxillary protrusion, maxillary retrusion, and mandibular prognathism. The criteria for classification and the number in each group were not given. His conclusions were the same as those in his later paper. (De Coster (1929), in which using the same material he applied the method of D'Arcy Thompson, (1917) constructing a grid using the Frankfort Horizontal as a base line.

He compared the grids of an unspecified number of Class III cases with the grids for normal cases. His main conclusions were that in 65% of his cases the measurement trignon - nasion, (cranial base) was increased, in 12% of cases the measurement trignon - naso-spinale (maxillary length) was decreased but was almost normal in the remainder. There was an increase in overall mandibular length but not always in horizontal ramus length and there was an increased facial height. He stressed the diverse morphology of Class III malocclusion and found only two "symptoms" common to all cases - the mesio-occlusion of the cheek teeth and the projection of gnathion in advance of the Orbital Plane of Simon. De Coster later adapted his grid system of analysis to lateral skull radiographs (1939) but no Class III cases were surveyed in this report.

Hellman studied the morphology of Class III malocclusion in several papers (1927) (1931) (1939). He compared the facial pattern of Class III cases with that of normal occlusion by means of facial diagrams constructed from facial measurements of living subjects and of skulls, in a similar manner to De Coster (1927). His principal conclusion in his study was "the occlusal relationship of the teeth in Class III malocclusion is only a relative one, i.e. - while the lower teeth are anterior to the upper it is not certain which of the two dental arches is in its normal antero-posterior position."

He considered the disturbance of occlusal relationships to be determined by disturbances in the harmonious development of the face as a whole and that either jaw might vary in dimension and position. In his 1931 study, Hellman compared 25 Class III cases with 62 cases of normal occlusion, all the subjects being adult male medical students. Using as his standard of normal \pm 1SD, he found:-

"The most conspicuous peculiarities of Class III faces are thus a supernormal face height associated with an open-bite, a subnormal upper face height with a super normal nasal height. The upper face is also very often shallow, (auriculo-prosthion) and the lower face, deep (auriculo-menton) and the mandibular angle often obtuse" and he concluded that "such investigations surprise one that Class III is so rare in view of the fact that there is so little difference between it and the normal when the face as a whole is taken into account."

Roentgenographic Cephalometric Studies of
Mesio-occlusion.

The first report of the use of radiographs to study mesio-occlusion is that of Hauptmeyer (1913) and his work is of historical rather than scientific interest. To judge by the illustrations in his paper a lateral oblique view of the skull was taken. Hauptmeyer did not record any measurements and basing his opinions on the interpretation of the radiographs came to the conclusion that in inferior protrusion (Class III) there is an increase in the length of the body of the jaw which has a slender ascending ramus and an obtuse angle.

Following this pioneer study no further references to Roentgenographic Cephalometric Studies of mesio-occlusion have been noted until after 1931, when Broadbent (1931) and Hoffrath (1931) quite independently of each other published their techniques for standardised roentgenographic cephalometry which have been employed in principle by all subsequent workers in this field, with individual modifications as regards the radiological technique and the method of analysis of the lateral skull radiograph. The first investigation, based on the Broadbent-Hoffrath techniques containing any data regarding mesio-occlusion, is that of Noyes, Rushing and Sims (1943) who examined the inclination of the upper and lower incisors in skulls and living

subjects. They found the upper incisors in the 15 Class III adult cases in their material to be more proclinated and the lower incisors more retroclinated than in the normal adult sample of 9 Indian skulls and 14 males.

In 1947 Bjork published his now classic paper "The Face in Profile". (Bjork 1947) His subjects comprised 322 twelve year old boys and 281 conscripts. There were 8 Class III cases among the boys and 26 among the conscripts.

Comparing the measurements of the 26 adult Class III cases with the mean for the whole adult material, Bjork found the mandibular base more prognathic and the maxillary base less prognathic than the mean, the alveolar prognathism in each jaw varied the same amount approximately as the bases and from this Bjork concluded "mandibular overbite" is on average due to relative differences in basal prognathism with local alveolar changes of minor significance. He found the maxillary incisors proclinated and the mandibular incisors retroclinated compared with the mean, thus tending to counteract the differences in basal prognathism. An analysis of the facial diagrams to determine which facial components had the greatest effect in increasing mandibular prognathism, showed the length of the maxilla to be less and that of the mandible to be greater than the mean, while the mandible (and its

articulation) was displaced forward relative to the maxilla, due to a reduction in the saddle (N-S-Ar) and joint (S-Ar-Go) angles and to a shortening of the "vertical arm of the cranial base", this latter difference being significant statistically. He concluded that the important factors were the relative change in size of maxilla to mandible and the changes in the facial diagram causing a forward displacement of the body of the mandible relative to the maxilla. Bjork found the same factors present in the 8 Class III cases among the boys.

Staff (1948) carried out a cephalometric appraisal of 57 cases of Class III malocclusion without regard to age, sex, or the severity of the deformity. He compared his results with those of Brodie's study of the growth of the face from 3 months to eight years in children with normal occlusion. (Brodie 1941). He concluded that the Class III skeletal pattern is an expression of the continuation of mandibular growth beyond normal limits. His conclusions are open to criticism on the grounds that he has assumed that because Brodie stated that he had found a stable growth pattern in children between 3 months and 8 years, that the same stability of relationship and proportion of parts persists throughout the whole period of growth and development. This misconception is prevalent in Orthodontic literature and ignores both the differential growth of parts, and the alterations in the relationships that are necessary for the transformation of the embryo into the adult (Barcroft 1946)

and takes no account of individual variation. It results from the confusion of the mean pattern of a serial study with that of the individuals comprising it. Recent roentgenographic cephalometric work is tending to concentrate on individual studies rather than on evidence gathered from observation of a group of individuals. For example, Moore (1959) says, "The concept of the constancy of the facial growth pattern was questioned when applied to the individual. Ample evidence was presented to demonstrate that variation not constancy is the rule."

Lande (1952) studying growth cephalometrically, found individual variation, with changes in the direction of growth of parts mostly continuing in the same trend but in some cases changing again back to the original direction. Of particular interest to this study was Lande's finding of a difference in growth behaviour between the maxilla and mandible, the mandible tending to become more prognathic with a mean tendency for this to occur after seven years.

Adams (1948) in a cephalometric investigation of mandibular form in various malocclusions, examined a random series of individuals. He found the Class III mandible to have a greater gonial angle and a narrower antero-posterior width of the ascending ramus. He also observed that the occlusal plane formed a more acute angle with the lower border of the mandible.

Schoenwetter (1948) examined the relationship of the upper and lower first permanent molars to the

face in 26 Class III malocclusions whose ages ranged from 4-29 years. He found the angle of the occlusal plane to the lower border of the mandible more obtuse than normal in contrast to the finding of Adams. He also found the height of the symphysis, (Gnathion to the tip of the mandibular incisor) to be greater in Class III and that the upper first permanent molar was further forward in relation to the cranial base. McCormick (1949), criticised these results of Schoenwetter's, pointing out that his assumptions are based entirely on slight differences in mean measurements and that no statistical tests of significance were applied. McCormick compared cephalometrically, 35 Class II Division (i) cases with 34 Class III cases none of which, clinically, showed any lateral or antero-posterior displacement of the mandible on closure. The age range was from 7 years to adult. His principal conclusions were "there are no essential differences in the relationships of the structures of the upper face, either to each other or to the cranial base, in cases of Class II Division (i) and Class III malocclusions, with the exception of variations in arch length."

Sanborn (1955) in the first roentgenographic cephalometric analysis of the total cranio-facial pattern devoted to mesio-occlusion only, compared a Class III sample of 42 adults, 26 males and 16 females of average age 21.8 years, the age range being 16-36 years, with a control sample of 35 adults, 26 males,

9 females, with excellent occlusion. The average age of the control sample was 24.6 years with a range of 16-38 years. Both the Class III and the control sample were of the white race. In the construction of his facial diagram, Sanborn used Bjork's articulare for the posterior end of the cranial base and the same method as used in this study for locating gonion, gnathion and the mandibular plane. Sanborn used Downs' occlusal plane and the Frankfort Horizontal and he related the axial inclination of the maxillary incisor to the palatal (maxillary) plane.

A summary of his principal findings is as follows-

1. A Class III malocclusion does not imply a typical skeletal pattern.
2. The most striking difference between Class III and the normal is the angle of convexity, (Downs) Fig. 3., with normal mean and S.D. of $1.24^{\circ} \pm 6.28$, compared with a Class III mean of $-13.48^{\circ} \pm 4.93$.
3. The maxilla tends to be less and the mandible more prognathic than normal.
4. The maxillary incisors are more proclinated and the mandibular more retroclinated than normal.
5. There is no significant difference in mandibular ramus length and height, but in Class III the gonial angle is more obtuse. Normal 123° , the S.D. ± 5.0 Class III 133.6° , S.D. ± 6.34 .

He found no significant difference in the saddle angle of Bjork (cranial base angle) but did find a significant difference in the joint angle of Bjork (\angle SArGo).

Sanborn does not discuss the cranial base measurements, only giving the length of S-N. which was:- Mean and S.D., normal 73.4 ± 3.7 and in Class III, 71.4 ± 5.0 mm. This difference, whilst not significant, approached significance with a "t" value of 1.99, (significant level $t = 2.0$).

Korkhaus and Neumann (1957) made a roentgenographic cephalometric comparison of 50 cases of "Progenia" (Class III) (divided into 19 deciduous dentition, 21 mixed dentition, 10 permanent dentition) with 39, 11-14 year old children with "anatomically correct occlusion." The ages of the Class III cases were not given. Their analysis was carried out according to the previously published methods of Korkhaus (1957). In comparison with the normal material they found in the Class III cases the following trends:- in the cranial base a decrease in length of the S-N line, in the maxilla a decrease in length and in the degree of prognathism and in the mandible a lengthening of the mandibular base Go-Gn, increased prominence of the chin and an increase in the mandibular angle.

Moss and Greenberg (1955) direct attention to the growth of the cranial base, comparing 49 adolescent children with malocclusion comprised of 28 Class II and 21 Class III, with 151 randomly selected

individuals in age ranging from the new born to adults. Their evidence indicated that only in the Class III group was there significant alteration from the normal in the spatial relations of the pre-sella pattern of the skull base, the cribriform angle being significantly smaller in the Class III group. This angle can be equated with the saddle angle (cranial base angle) of Bjork.

Jean (1957) compared cephalometrically, 20 cases of Class III (age range 6-27 years) with an unstated number of normals. Individual and mean dimensions of the Class III and the mean dimensions only of the normal cases are given. Comparing the means of the Class III and normals, he found in the Class III cases an increase in mandibular prognathism, the mandibular (gonial) angle and mandibular linear dimensions, and a decrease in maxillary length and prognathism. The upper incisor was more proclinated and the lower incisor more retroclinated. The differences between the Class III and normal means were not great e.g. - 0.9, 1.7 and 0.7mm for the overall, vertical and horizontal dimensions of the mandible and in the absence of more statistical data their significance cannot be assessed.

A recent paper by Maj, Luzi, Lucchese (1958), presented in 1958 but not published until 1959, gives the results of a roentgenographic cephalometric analysis of 50 Class III malocclusions comprised of

boys and girls of from 8-15 years of age compared with a similar group of normal children. Their findings are difficult to assess because the data published is inadequate and the method of analysis (Maj et al 1957) is more geometrical than anatomical. Summarising their findings they found protrusion of the mandible relative to the maxilla in 78% of cases due either to an increase in size of the mandible or a more forward position of the mandibular articulation. The mandibular increase was due to increased horizontal length, the mandibular angle was "not disturbed." The inclination of the upper incisors was within "normal range", while the lower incisors were retroclined. In general lines the skeletal and dental pattern is "like one of the normal orthognathic type."

Summary.

A comparison of the findings in the papers quoted is difficult both on account of the diverse nature of the samples studied and the varying reference points employed. No information is available as to the methods employed in the craniometric studies on skulls by Sicher and Krasa, Grieve and Pfaff. In the biometric studies of Hellman and De Coster, Hellman used a head-spanner which gave the distance of the profile points from the trans-porionic axis in the median sagittal plane. De Coster on the other hand used simple dividers and his measurements from tragion to points on the profile would be influenced by the facial breadth.

In the various roentgenographic cephalometric

studies, it is not possible to compare the findings quantitatively because of the unknown factors of magnification and distortion in each case and also because of the varying reference points used to construct the lines and angles measured and the methods of analysis employed. For instance Bjork's gnathion differs from that of Sanborn and would give a slightly larger value of the gonial (or mandibular) angle, whilst Korkhaus and Neuman's use of tragon instead of articulare, results in a larger value again for the gonial or mandibular angle, whilst the analytical method of Maj and his colleagues differs markedly from those of other investigators.

Despite these difficulties it is possible to compare the various findings in terms of their general trends which may be summarised as follows:-

Cranial Base. The general conclusion is of the probability of the cranial base being foreshortened due to an increased flexure. Bjork, Sanborn, Korkhaus and Neuman, Moss and Greenberg, all support this finding either in terms of decreased linear or angular components or both. Sicher and Krasa's finding of an increased basion-nasion distance is offset by Grieve's contradictory conclusions regarding the same material. More weight can be given to De Coster's findings of an increased tragon-nasion distance in 65% of his patients, but in the absence of fuller data than is given in his paper, one can only speculate as to the reason for this difference between his findings in this respect and those of the majority.

Mandible.

With the exception of Maj and his associates, it is generally agreed that the mandibular angle is more obtuse. Bjork did not find the angular difference significant but Sanborn did. There are differences in the linear dimensions. Bjork found a relative, rather than absolute increase in mandibular length when compared with the maxillary length. Korkhaus and Neuman, De Coster and Maj et al. found the horizontal component Go-Gn increased. Hellman found mandibular dimensions variable and Sanborn found no significant difference in the length of the vertical and horizontal components. The general conclusion is that the mandibular size is variable and may be larger than normal or within the normal range of variation, the relative size of the maxilla being an equally important factor.

Maxilla.

De Coster, Korkhaus and Neuman, and Jean, all found a decrease in mean maxillary length, De Coster in 12% of cases only. Hellman states the length is variable whilst Bjork finds a decrease relative to the length of the mandible.

Prognathism.

As is to be expected there is general agreement that the mandible is relatively more prognathous than the maxilla. Grieve, Korkhaus and Neuman, Sanborn, Bjork and Jean, all describe the maxilla as less

prognathous and the mandible as more prognathous than normal. Sanborn goes further and groups his patients into combinations of various degrees of maxillary and mandibular prognathism.

Incisal Relationships. Only Noyes et al., Bjork, Sanborn and Jean record the axial inclinations of the upper and lower incisors. They all find the upper incisors more proclinated and the lower incisors more retroclinated than normal. Maj et al. differ in describing the upper incisors' inclination as within normal range.

It is necessary to keep in mind in considering the papers reviewed above that the authors have mostly drawn their conclusions from a study of mean differences in various linear and angular values and apart from Bjork and Sanborn, have not applied statistical tests of significance to their figures. An examination of the range of the Class III measurements where given shows many of them to be within the range of values of the comparable normal dimensions. This suggests that the cranio-facial pattern associated with a Class III malocclusion is not a single entity sharply demarcated from the normal by certain clearly definable differences of size form or relationship and that there exists varying degrees of malrelations and proportions of parts concerned which give rise to the varying degrees of mesio-occlusion observed clinically

The principal cephalometric studies of mesio-occlusion published since this work was started, are those of Sanborn (1955) Korkhaus and Neuman (1957)

Jean (1957) and Maj et al. (1958). Of these, only Sanborn's mean differences between normal and Class III were tested for statistical significance. Whilst his sample was adequate statistically, in numbers, it covered only the permanent dentition. The individual age groups were not given and it comprised both sexes. Korkhaus and Neuman (1957) cover all dentitional groups, the mixed dentition group however numbered only 10 children which was the only group for which there was comparable normal material (39 children who were from 11-14 years of age.) The sample of Maj et al. includes both mixed and permanent dentition cases (8-15 years). Jean's sample of 20 individuals of ages ranging from 6-27 covered too wide a span of growth and development. The number of Class III cases in all these studies totals only 218 individuals. There is therefore a need for more information concerning the nature of the Class III cranio-facial pattern at all stages of development. The present study numbers 226 cases of Class III malocclusion, 22 in the deciduous dentition, 128 in the mixed dentition and 76 in the permanent dentition.

Material.

The patients for this study were taken from those attending the Orthodontic Department of the Edinburgh Dental Hospital.

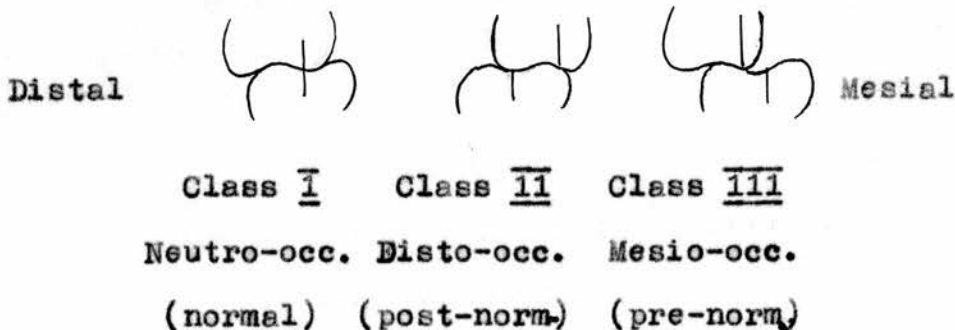
They were classified according to Angle's Classification of malocclusion, Angle (1899), which is briefly as follows:-

Class I. Normal occlusion of the first permanent molars with malocclusion of one or more teeth:-
Neutro-occlusion.

Class II. Distal occlusion of the lower first permanent molar with the upper first permanent molar:-
disto-occlusion. Division(i) proclined upper incisors; Division(ii) retroclined upper central incisors and proclined upper lateral incisors.

Class III. Mesial occlusion of the lower first permanent molar with the upper first permanent molar:-
mesio-occlusion.

Before classifying a malocclusion, allowance is made for mesial drifting of the first permanent molars in cases showing premature loss of the deciduous molars anterior to them.



Occlusal relationships of the first permanent molars in Angle's classification.

(Note: In normal occlusal relationships of the first permanent molars, the anterior buccal cusp of the maxillary first permanent molar occludes in the anterior buccal groove of the mandibular first permanent molar.)

In both normal occlusion and Angle's Class I malocclusion, the first permanent molars are in "neutro-occlusion".

In diagnosing cases on the border line between Class I and Class III where the picture was often complicated by the premature loss of one or more deciduous molars, the occlusion of the canines and the general clinical appearance were taken into account. Angle's original statement that in Class III the mandibular molar was a premolar width mesial has had to be modified. It has been found in clinical practice that such a test of mesio-occlusion would include in Class I, many cases that skeletally and occlusally were Class III and which, from the point of view of treatment, require to be treated as such.

The subjects comprised 226 patients diagnosed clinically as Angle Class III malocclusions (mesio-occlusion) in future designated "Class III", who were compared with 157 patients showing either normal occlusion or Angles Class I malocclusion, in future referred to as "Neutro-occlusion."

Since the essential features under investigation are the skeletal features associated with mesio-

-occlusion and since in both Angle's Class I and normal occlusion the first permanent molars are in Neutro-occlusion, it was felt permissible to combine these groups for purposes of comparison. No attempt was made to ascertain the number in each of these latter groups for two reasons, firstly the normal group was very small and secondly many of the Class I malocclusions were basically normal, exhibiting either transient anomalies arising in the course of occlusal development, or malocclusions due to local causes which the available evidence suggests do not influence the basic skeletal pattern (Brash 1929), and it is being assumed that this is so for the purpose of this study. The remainder of the Class I malocclusions apart from miscellaneous conditions such as cross bite were cases showing general crowding usually in both arches. In so far as the crowding was limited to the upper jaw and was due to a small jaw in relation to the amount of tooth material, the inclusion of these cases is open to criticism since maxillary-mandibular disproportion is thought to be a prime cause of mesio-occlusion. One can justify their inclusion however on the ground that even if, in these Class I cases, there is a maxillary mandibular disproportion, it is not of such a nature or degree as to produce mesio-occlusion and

their presence in the control material should set as a check upon any undue weight being given to minor differences in maxillary mandibular proportions.

The age range of both the Class I and the Neutro-occlusion was from 4 years to 21 years. The age division of both groups is presented in Tables 1 & 2.

The material was divided into three groups according to dental age rather than chronological age as follows:- (1) "deciduous" (2) "mixed" and (3) "permanent dentition" groups. It was not possible to refine the grouping by using a method of dental ages such as that of Hellman (1927), owing to the great number of children who had suffered premature loss of several deciduous molars. The criteria used to decide the classification of a particular dentition were the occlusion of the first and second permanent molars as follows:-

1. Deciduous dentition. All children in whom the first permanent molars were not in occlusion.

2. Mixed dentition. All children showing occlusion of the first permanent molars but not of the second permanent molars.

3. Permanent dentition. All children showing occlusion of the second permanent molars. The use of the occlusion of the first and second permanent molars resulted in some patients being classed as deciduous dentition who had lower permanent central

Table 1.

Showing the distribution in age and dentitional groups of the Neutro-occlusion (Class I and Normal occlusion) material.

NEUTRO-OCCLUSION.										
Age	Deciduous Dentition			Mixed Dentition			Permanent Dentition			Age Groups Combined Totals
	M	F	Total	M	F	Total	M	F	Total	
4	2	3	5							5
5	3	2	5							5
6	2		2	2	1	3				5
7	1		1	9	1	10				11
8				4	12	16				16
9				6	8	14				14
10				3	15	18				18
11				16	10	26	3		3	29
12				3	6	9	3	7	10	19
13				2	1	3	3	5	8	11
14				2		2	1	2	3	5
15							1	5	6	6
16							1	4	5	5
17							3		3	3
18							1		1	1
19							1		1	1
20										
21							3		3	3
	8	5	13	47	54	101	9	34	43	157

Table 2.

Showing the distribution in age and dental groups of the Class III material.

Class <u>III</u>										
Age	Deciduous Dentition			Mixed Dentition			Permanent Dentition			Age Groups Combined Totals
	M	F	Total	M	F	Total	M	F	Total	
4	1		1							1
5	4	5	9							9
6	7	3	10	1	1	2				12
7	1	1	2	8	7	15				17
8				8	15	23				23
9				13	17	30				30
10				22	13	35				35
11				4	10	14		2	2	16
12				2	2	4	1	8	9	13
13				1	2	3	3	9	12	15
14				2		2	2	12	14	16
15							4	6	10	10
16							1	3	4	4
17							3	6	9	9
18							2	3	5	5
19								2	2	2
20								1	1	1
21							5	3	8	8
	13	9	22	61	67	128	21	55	76	226

incisors erupted and in some cases being classed as permanent dentition who still had deciduous molars or canines present. It was however considered that the occlusion of the first and second permanent molars respectively represent landmarks in occlusal development and imply the necessary growth in arch length to accommodate them.

A study of the tables shows that in both the Class III and the Neutro-occlusion groups, as one would expect, there is a marked overlapping in chronological ages both between the deciduous and mixed and between the mixed and permanent dentition groups.

With regard to the differences in the numbers in each group it should be explained that the Class III cases were collected as they presented and it was not until the material was grouped in ages that any indication of the size of each group was obtained. It is unfortunate that more children could not be obtained both for the deciduous dentition groups and for the permanent dentition neutro-occlusion male group but field work to collect material was not possible. The disadvantage in the size of these two samples could have been overcome from a numerical viewpoint by combining the male and female groups for all the material but apart from Bjork's work which compared 12 year old boys with young adults and the

works of Werner (1955) and Coben (1955), which give data concerning separate groups of boys and girls. There appears to be little information about either sex as such, the majority of the studies involving mixed samples. It was therefore decided to accept the disadvantages in these two samples. It is hoped to continue the compilation of data on this study and the long term result will, it is hoped, remedy the present shortcomings.

In general girls outnumber boys by 131-95 in the Class III group and by 96-61 in the Neutro-occlusion group; only in the deciduous dentition do boys outnumber girls; the reason for this latter is not clear as it is usual in an Orthodontic department for girls to outnumber boys, probably because of a greater concern with appearance on the part of both girls and the parents of girls. It is not necessarily an indication of greater incidence of malocclusion in girls than in boys.

It will also be seen when the figures for Class III treatment are considered, that not all the patients in the Class III group received treatment, the reasons being that treatment was not indicated where the overjet and overbite were normal, or the bite was edge to edge, and as some patients were not treatable Orthodontically they were referred for surgical treatment. Others declined treatment and some patients left the district.

The Roentgenographic Method Employed.

All the lateral skull radiographs were taken with the patient positioned in a Shandon Cephalometer with the head orientated in the Frankfort Plane. The distance from the X-ray tube to the centre of the cephalostat (median sagittal plane of the patient) was 64.5" and from the centre of the cephalostat to the film, the distance was 7.5". The total distance from anode to film being 72". The X-ray tube was centred on the ear rods of the cephalometer. The X-ray tube was a Watson Dynamax 25, using 100 MA at 63-67.5K.V. for 1.2 - 1.5 seconds. The K.V. and exposure time being varied by the radiographer according to the age and development of the patient.

The film used was Ilford High Definition 10" x 12", placed in a cassette between intensifying screens. Since only the profile views were required in the soft tissue exposure, a 10" x 12" film was cut into three strips and a strip of film 12" x 3" approximately was placed in the cassette in front of the intensifying screens in the appropriate position. This procedure reduces film consumption by 33% and is a considerable economy where large numbers are involved.

Radiation Hazard.

Since this study was started there has been a growing emphasis on the dangers of radiation. The

average "r" dosage has been kindly calculated by Mr. A. R. Bradshaw, as 0.6r per lateral skull exposure which compares very favourably with the exposure for other dental radiographs. As a safety measure a lead apron is stretched across the frame of the cephalostat shielding the patient from shoulder level downwards.

Tracing and Measuring Technique.

Tracings of the films were made on fine tracing paper using a 9H pencil and the various landmarks employed marked. The planes and angles to be measured were then constructed. The linear measurements were made in millimetres with fine pointed calipers, having a Vernier scale reading to 1/10mm. The angular measurements were made with a circular protractor of 4" radius giving clear readings of 0.5°.

Definitions of points and planes employed as basis for linear and angular measurements. Figs. 1, 2, 3.

A. Downs' point A - subspinale the deepest mid-line point on the premaxilla between the anterior nasal spine and prosthion.

B. Downs' point B - supramentale the most posterior point in the concavity between infra dentale and pogonion.

A'. The point of intersection with the maxillary plane of a perpendicular to the maxillary plane from point A.

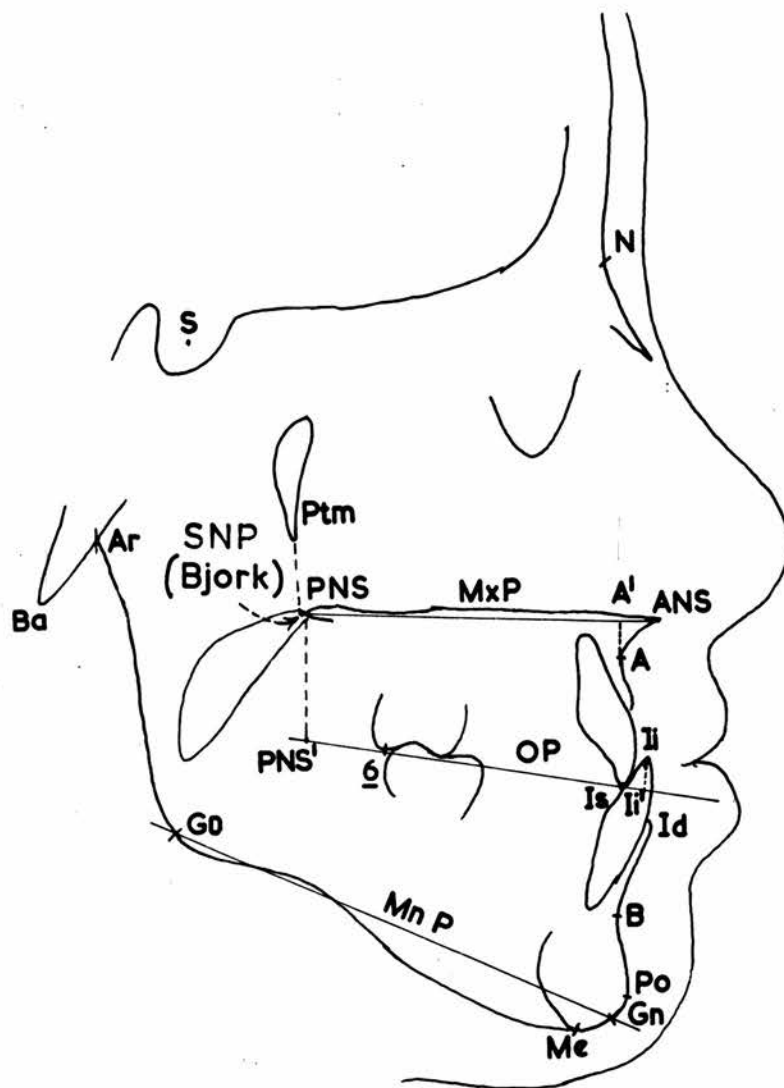


FIG. 1.

FIG. 1. Anatomical and constructed points and planes employed in the cephalometric analysis.

Note Figs 1, 2 and 3 are duplicated at the end of the thesis in fold out form for ease of reference.

ANS. Anterior nasal spine. - The tip of the anterior nasal spine as seen in norma lateralis.

Ar. Articulare - "A point formed at the (intersection of the)¹ contour of the external cranial base and the dorsal contour of the condylar process." (Bjork and Palling 1954).

Ba. Basion - The lowermost point of the anterior margin of the foramen magnum in the mid-sagittal plane.

Gn. Gnathion - A point on the symphysis obtained by bisecting the angle formed by a line from menton tangent to the lower border of the mandible in the region of the angle of the mandible with a line from nasion tangent to pogonion.

GO. Gonion - A point on the bony contour of the gonial angle obtained by bisection of the angle formed by the intersection of a line from Ar tangent to the posterior border of the mandible with a line from menton tangent to the lower border of the mandible in the region of the angle of the mandible.

Id. Infradentale - The point of transition from the crown of the most prominent mandibular medial incisor to the alveolar projection (Bjork).

Ii. Incision inferius - The incisal point of the most prominent medial mandibular incisor.

Ii'. The point where a line from Ii perpendicular to the occlusal plane meets the occlusal plane.

Is. Incision superius. - The incisal point

¹ Additional to the definition as given by Bjork and Palling. Its omission by them may be accidental.

of the most prominent medial maxillary incisor.

is. Point where projection of long axis of maxillary incisor meets the maxillary plane (MxP).

L. Point where projection of long axis of mandibular incisors meets the mandibular plane.

Me. Menton - The lowermost point of the symphyseal shadow as seen in norma lateralis.

MxP. The maxillary plane formed by a line connecting the tip of the anterior nasal spine and the tip of the posterior nasal spine.

MnP. The mandibular plane formed by a line joining Gn and Go.

N. Nasion - The most anterior point of the fronto-nasal suture as seen in norma lateralis.

O.P. Occlusal plane - A plane formed by a line joining Is to the posterior cusp of the maxillary first permanent molar or the anterior cusp of the second permanent molar if the first molar is absent. (In the deciduous dentition the distal cusp of the second deciduous molar is used.)

O.P'. Point of intersection of OP by line ANS-GN.

Po. Pogonion - The most anterior point of the chin as seen in norma lateralis.

PNS. Posterior nasal spine - The junction of the hard and soft palates as seen in norma lateralis. (Where this could not be seen because of the position

of a developing molar, Bjork's SNP was used. This is described as "Intersection of pterygo-palatine fossa with junction of hard and soft palate."

Bjork (1947).

PNS'. The point where a perpendicular line from PNS meets the occlusal plane.

Pr. Prosthion - The transition point between the crown of the most prominent medial maxillary incisor and the alveolar projection (Bjork 1947).

S. The centre of the sella turcica as determined by inspection.

U. Point on SN where projection of long axis of the upper incisor meets the line SN.

6 The tip of the distal buccal cusp of the first permanent molar (mesial buccal cusp of 7 if 6 is lost.)

Discussion of Points and Planes.

The points and planes are those generally employed in roentgenographic cephalometric analysis. Where the differences of definition exist as in the case of menton and gnathion and in the location of the mandibular plane, the usage followed agrees with the recently published recommendations of Krogman and Sassouni (1957).

The definition of the occlusal plane follows Bjork (1947), rather than the more generally used definition of Downs (1948). Downs' definition is as

follows - "Occlusal plane - a line bisecting the occlusion of the first molars and central incisors. Should either incisor lack full eruption or be in supra or infra occlusion the general occlusion as determined by the premolars is used."

The Downs occlusal plane was found impractical for two reasons. One was that in many cases it was not possible to draw a line that bisected both the molar occlusion and the incisor occlusion, the other reason was that in most of the mixed dentition cases the deciduous molars had been lost and the premolars were not erupted. Bjork's plane has the merit that there is never any difficulty in constructing it as it involves joining only two easily defined points. The difficulty is in deciding what relation it bears to the occlusal plane which shows a varying amount of curvature. In Class III cases with anterior open bite a line joining the molar cusp to the incisal tip rises anteriorly and will bear little relation to the occlusal surfaces of the premolars. In the assessment of after-treatment changes the plane will be affected by proclination of the upper incisors giving the impression that the occlusal plane has tilted up anteriorly and been depressed posteriorly with little relation to any actual alteration in axial inclination of the molars. Bjork's occlusal plane has

been used as the least unsatisfactory but with reservations as to the value to be given to any findings involving its employment.

Articulare was used both as the dorsal end point of the cranial base and as a substitute for the condylar head. Basion, the true dorsal end of the cranial base, was often difficult to pick out accurately and the mandibular condyle was seldom definable, therefore whilst preferable to articulare, these points could not be employed. It must be remembered that in using articulare as a mandibular point one is assuming in comparing one mandibular length, as expressed by the distance Ar-Gn, with another, that the length of condyle head obscured by the shadow of the cranial base is the same in both cases and that the thickness of the interarticular disc does not vary significantly.

S-Ar, besides being an approximate measure of the posterior length of the cranial base, is also an indirect measure of the antero-posterior position of the temporo-mandibular articulation in relation to point sella and thus to the anterior cranial base and maxilla.

Linear and Angular Measurements.

Cranio-facial diagrams from the tracing for each subject were constructed and the following linear and angular measurements were made using the points and planes defined (Fig. 1). The linear measurements were made to 1/10th of a millimetre and the angular measurements to the nearest half degree. Each measurement was given a number and is referred to as Linear 1 or Angular 1 etc. and are designated in the various tables as L1, L2, A1, A2 etc., for brevity.

Linear Measurements (M). Fig. 2, 3.

<u>M. Between Points.</u>				<u>M. Between Points.</u>			
L1	S - N	Fig 2 (A)		L14	N - Id	Fig 2 (B)	
L2	S - Ar	" (A)		L15	N - B	" (B)	
L3	Ar - N	" (A)		L16	N - Po	" (B)	
L4	Ar - Go	" (A)		L17	ANS - GN	" (A)	
L5	Go - Gn	" (A)		L18	ANS - OP'	" (C)	
L6	Ar - Gn	" (A)		L19	GN - OP'	" (C)	
L7	PNS - ANS	" (A)		L20	Is - is	" (A)	
L8	PNS - A'	" (B)		L21	Ii - L	" (A)	
L9	PNS - PNS'	" (A)		L22	N-ANS+ANS-GN	" (A)	
L10	N - ANS	" (A)		L23	Ii - Ii'	" (D)	
L11	N - A'	" (B)		L24	Is - Ii'	" (D)	
L12	N - A	" (A)		L25	PNS' - <u>6</u>	" (A)	
L13	N - Pr	" (A)					

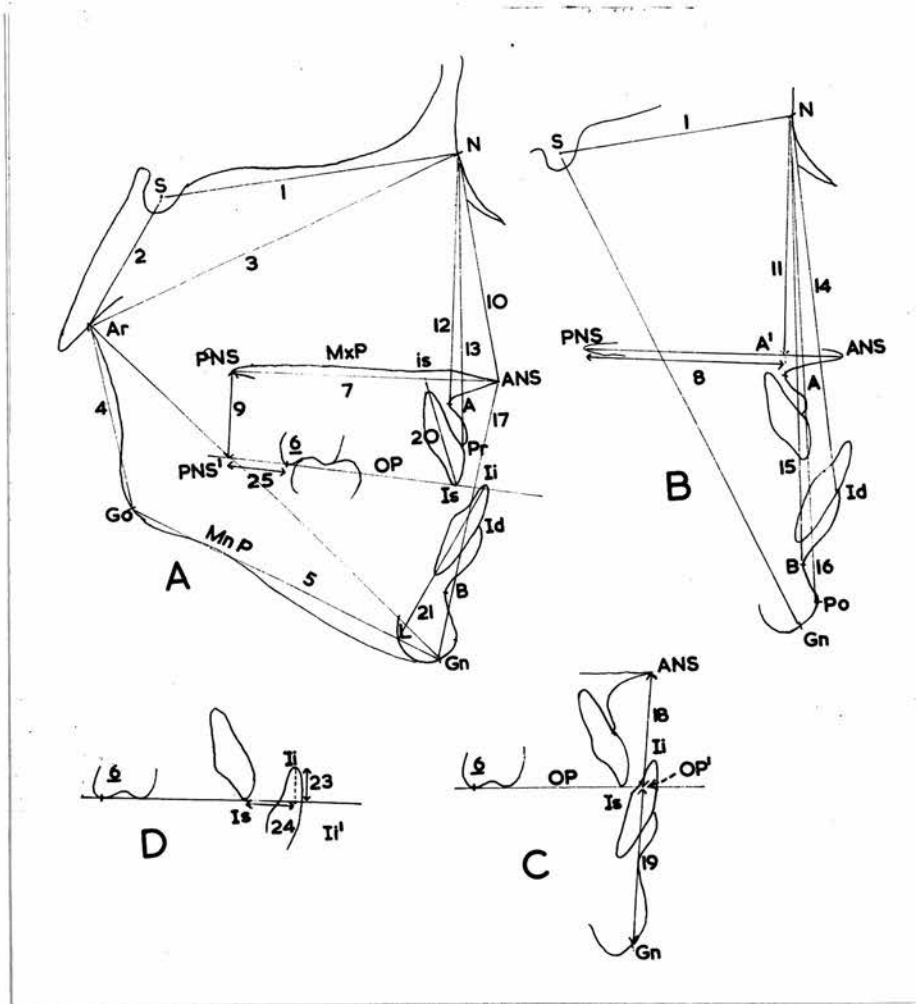


FIG. 2. Diagrams illustrating the lines and angles measured in the cephalometric analysis.

Angular Measurements in Degrees.N. Notation.

- A1 \angle NSAr Angle between lines 1 and 2 Fig. 2A
- A2 \angle SARGo Angle between lines 2 and 4 Fig. 2A
- A3 \angle ArGoGn Angle between lines 4 and 5 Fig. 2A
- A4 \angle SNA Angle between lines 1 and 12 Fig. 2A
- A5 \angle SNB Angle between lines 1 and 15 Fig. 2B
- A6 \angle SNPr Angle between lines 1 and 13 Fig. 2B
- A7 \angle SNId Angle between lines 1 and 14 Fig. 2B
- A8 \angle SNPo Angle between lines 1 and 16 Fig. 2B
- A9 \angle NAPo Recorded as the complement of angle between lines NA and APo, Fig. 3A. Recorded as negative if A lies behind NPo. When N, A and Po lie on a straight line, the reading is 0. "Downs' angle of convexity."
- A10 \angle OP/SN Angle between line (S-N) and occlusal plane Fig. 3B. "Occlusal Plane Angle."
- A11 \angle MnP/SN Angle between lines 1 (S-N) and 5. (mand. plane) Fig. 3B. "Mand. Plane Angle."
- A12 \angle IsU/SN Postero-inferior angle formed by intersection of line at "U" by projection of long axis of upper incisor. Fig. 3B.
- A13 \angle Ii-L/MnP Postero-superior angle formed by the intersection of the mandibular plane at "L" by the projection of the long axis of the lower incisor. Fig. 3B.

Angular Measurements in Degrees Contd.N. Notation.

- A14 $\angle UIs/iIL$ Internal angle formed by intersection of long axis of upper and lower incisors. Fig 3B.
"Interincisal angle."
- A15 $\angle NSGn$ Angle between lines NS and SGN Fig. 3B. "Y axis."
- A16 $\angle MnP/OP$ Angle between mandibular plane and occlusal plane Fig. 3B.
- A17 $\angle MxP/SN$ Angle between maxillary plane and line SN. Fig 3B. "Maxillary Plane Angle."
- A18 $\angle MxP/OP$ Angle between maxillary plane and occlusal plane, Fig. 3B.
- A19 $\angle IdPo/MnP$ Angle between forward projection of the mandibular plane and the projection from Po of a line joining Id-Po. Fig. 3B. "Chin Angle"

Discussion of Linear and Angular Measurements Employed

In choosing the dimensions and angular relationships to measure, there were two chief considerations. One was the accuracy with which the reference points could be determined, this is discussed under "Errors", and the other was to choose points whose relationships to each other would as far as possible represent the relationship of anatomical structures to each other rather than their relationship to some arbitrary point in space.

The anatomical structures (or complexes) studied were, the cranial base, the mandible, the maxilla and the face in profile. Ideally the cranial base would be measured from basion to the foramen caecum. As already mentioned basion was excluded, articulare being substituted. The foramen caecum is rarely discernible. Nasion, the generally accepted substitute, was used. When serial studies of treated cases were made, nasion was found to have a disadvantage. This is discussed in the description of the technique of superimposition used in the serial study.

The anterior portion of the cranial base S-N is influenced by growth at the spheno-ethmoidal synchondrosis. Changes in the distance S - Ar, do not necessarily reflect growth at the spheno-occipital synchondrosis because articulare is not a fixed point.

on the cranial base but is dependent on the position of the neck of the condyle. The overall length of the cranial base is given by the distance N-Ar.

Mandibular dimensions were measured by; Ar-Go vertical ramus height, Go-Gn horizontal ramus length and Ar.-Gn overall length. Anterior occlusal height was measured by Ii-MnP.

The various components of face height were recorded by the following measurements:- N-ANS (10), N-A' (11), N-A (12), N-Pr (13), N-Id (14), N-B (15), N-Po (16), ANS-Gn (17) ANS-OP' (18), 'OP-Gn (19), N-ANS+ANS-Gn (22).

The maxillary length is measured by ANS-PNS (7), posterior height occlusally by PNS-PNS' (9) and anteriorly by Is-is (20). The height of the maxilla above the maxillary plane was measured anteriorly by N-ANS (10).

An additional measurement of maxillary length PNS-A' was made. A' being determined by dropping a perpendicular from point A to the maxillary plane. The anterior nasal spine as seen radiographically varies from a short blunt process to an elongated spine, the tip of which merges into the surrounding shadows. This makes for variation in its location. It was thought that PNS-A' might give a more reliable estimate of maxillary length and also represent, from a tooth supporting view point, the maximum length of basal bone. This is an approximation and it is

incorrect to describe Point A as being level with the maxillary incisor apex and representing anatomically the anterior limit of maxillary basal bone.

Angular relations.

The cranial base angle NSAr and "jaw angle" SARGo employed by Bjork (1947), were used. With regard to the mandibular angle, ArGoGn (3), when comparing its values with those obtained by other workers the points used in its construction must be borne in mind. For instance, Bjork uses menton (called gnathion by him) for his symphyseal point which will give slightly larger values than those obtained by using the gnathion as defined by Krogman and Sassouni (1957) and used in this study. Angles 4-8 give the degree of prominence of the profile points A (4), B (5), Pr (6), Id (7), Po (8), as expressed by the angles they form with the S-N line.

Angles 17, 10 and 11, give the angular relationship of the maxillary, occlusal and mandibular planes to the anterior cranial base line S-N and angles 16 and 18 give the relationship of the occlusal plane to the maxillary and mandibular planes, whilst the difference between angles 11 (mandibular plane to S-N) and 17 (maxillary plane to SN) gives the angular relationship between the maxillary and mandibular planes.

The axial inclination of the upper incisor (12) was related to the S-N plane. Some writers now

relate the upper incisors to the maxillary plane, this angle can be deduced from the available data, it is equal to the sum of angles 10 and 17.

The mandibular incisor is related to the mandibular plane (A13). The interincisal angle is A14 and the so called "Y" axis $\angle N-S-Gn$ is A15. The chin angle of Bjork (1947) is formed by the intersection of a line joining infradentale and pogonion with the mandibular plane. This angle reflects changes both in the angulation of the lower incisor and of the prominence of the chin. It will be noted that the Frankfort Horizontal plane has not been employed as a reference plane in the analysis although used to position the patient's head in the cephalometer. Cephalometric porion is based on the metal shadow of the ear rods and experience showed that there was considerable variation in the positioning of the ear rods with the same radiographer and the same patient on different occasions. This agrees with the findings of Steiner (1953). The Frankfort Horizontal was rejected by Bjork (1947) as less reliable than S-N and Koski (1953) also does not favour its use.

Errors of the Method.

The sources of error may be considered under three headings:-

1. Those arising from variations in radiographic technique.
2. Those arising from variations in determining the cephalometric landmarks employed.
3. Those arising from errors of measurement.

1. Radiographic Technique.

As described earlier this was a standardised procedure with the patient adjusted in the cephalometer so that the head was orientated in the Frankfort Plane and the distances from the anode to the mid-sagittal plane of the patient and from the film to the mid-sagittal plane were constant .

Magnification and Distortion.

With a standard distance and correct head positioning one can assume that the magnification factor is the same in all films. This subject has been discussed amongst others by Adams (1940), Bjork (1947) and Hallett (1959). Adams discusses the use of corrective scales but while advocating their use he concludes that "there is no substitute for painstaking technique." Bjork (1947) emphasizes that "the measurements quoted in this work are all projections of the actual measurements, a fact which, although not referred to again, should not be taken for granted." Hallett (1959) lists the various

sources of distortion and emphasizes the need for stability of the cephalometer and of the patient in the cephalometer, the use of short exposure time and the anode film distance. Hallett deals with the problem of magnification and distortion by the ingenious use of a pantograph capable of correcting the various magnifications of the original tracing. His method however is of recent publication and was not available when the measurements were being carried out.

A simple experiment was carried out to demonstrate the varying amount of magnification of the dimensions measured. A skull was placed in the cephalometer with lengths of stainless steel tubing placed along the median plane of the palate, across the foramen magnum and along the posterior border of the horizontal ramus of the mandible. Measurement of the length of the rod compared with its projected shadow on the film showed, as Bjork (1957) and others have observed, that a magnification of 10-12% is obtained of dimensions in the median sagittal plane, and that the magnification is reduced by distortion in planes not parallel to the median sagittal plane. Table 3 shows the measurements obtained. Of particular significance to this study is the observation that if the magnification and distortion

factor for each dimension is not known, it is not possible to compare linear dimensions obtained with different radiographic techniques, as regards anode-patient-film distances and centering of the X-ray tube, but does not prevent the comparison of dimensions within the same series, although as Bjork (1947) points out, there is the effect of varying breadth of the face to consider which will effect dimensions not parallel to the median plane.

Table 3.

Actual and magnified measurements of wire inserts placed as indicated on a skull and X-rayed in the cephalometer.

Length of Tubing in MM.

Location of wire insert	A	X	I	%I
Maxilla ANS-PNS	51.3	57.8	6.5	10.7
Mandible Vertical Ramus	57.8	62.9	5.1	8.8
Mandible Horizontal Ramus	90.3	92.3	2.0	2.2
Foramen Magnum A/P Diameter	36.0	40.5	4.5	12.5
Ant.Border Sella-Foram.Caecum	46.5	52.5	6.0	12.9

A= Actual measurement. I = Increase
 X = Measurement on X-ray film. %I = Increase. Percentage

Angles are less affected. Hallett (1959) states "Sagittal angles alter too little to make any significant difference, lateral angles e.g. the gonial, away from the central axis open 1-2° (agrees with

Adams)". These errors of magnification and distortion are inherent in the method and must be kept continually in mind.

2. Errors in Determining Cephalometric Landmarks

Bjork (1947) conducted a painstaking and meticulous test of the reliability of various reference points and planes. The points and planes used in this study are among those that he found reliable. Dick (1953) investigated the variability of cephalometric landmarks, as determined by different observers in the same film. She concluded that "well trained observers do not always designate the cephalometric landmarks on the same location." Dick grouped landmarks according to the degree of dispersion and found sella turcica, nasion, maxillary and mandibular incisor tips, gnathion and articulare among the least variable, the most variable point being "glenoid fossa." Dick does not record the consistency of individual observers in re-marking out the same landmarks on the same film. A test of this was made first by marking the points employed on a radiograph of the same patient on five different occasions and superimposing the tracings on a common reference frame of horizontal and vertical lines. When viewed by transmitted light a high degree of concordance was seen, sella, nasion, articulare, incisal and mandibular outlines being least variable.

More variation was found with ANS, PNS, tip of posterior cusp of 6 and points such as A and B on the alveolar profile.

The results obtained have been reproduced photographically, employing a method suggested by Professor Romanes. (Fig. 4) This consisted of drawing the horizontal and vertical reference lines on a piece of thin card under which was another piece of card with a carbon paper between. Each tracing was then aligned on the reference lines on the top card and the landmarks impressed with a stencil pen. A slight blurring of the marks results from the carbon but it gives a good indication of the degree of variance in locating the points and landmarks.

A further test was done to show the effects upon the linear and angular measurements of variation in location of the landmarks by repeating tracings and measurements of six cases. A marked difference in measurement was not expected as the greatest dispersion of the points for any one landmark did not exceed 1.5mm. and as this was for point A and occurred in a vertical direction so that its effect on the important angle SNA would be slight. Some variation in maxillary length was expected as ANS in some cases ends in a very fine point which tends to merge with the surrounding shadows at its extremity. The results of this check are given in detail in the appendix.¹ Before commenting on them, mention should

¹ Section IV.



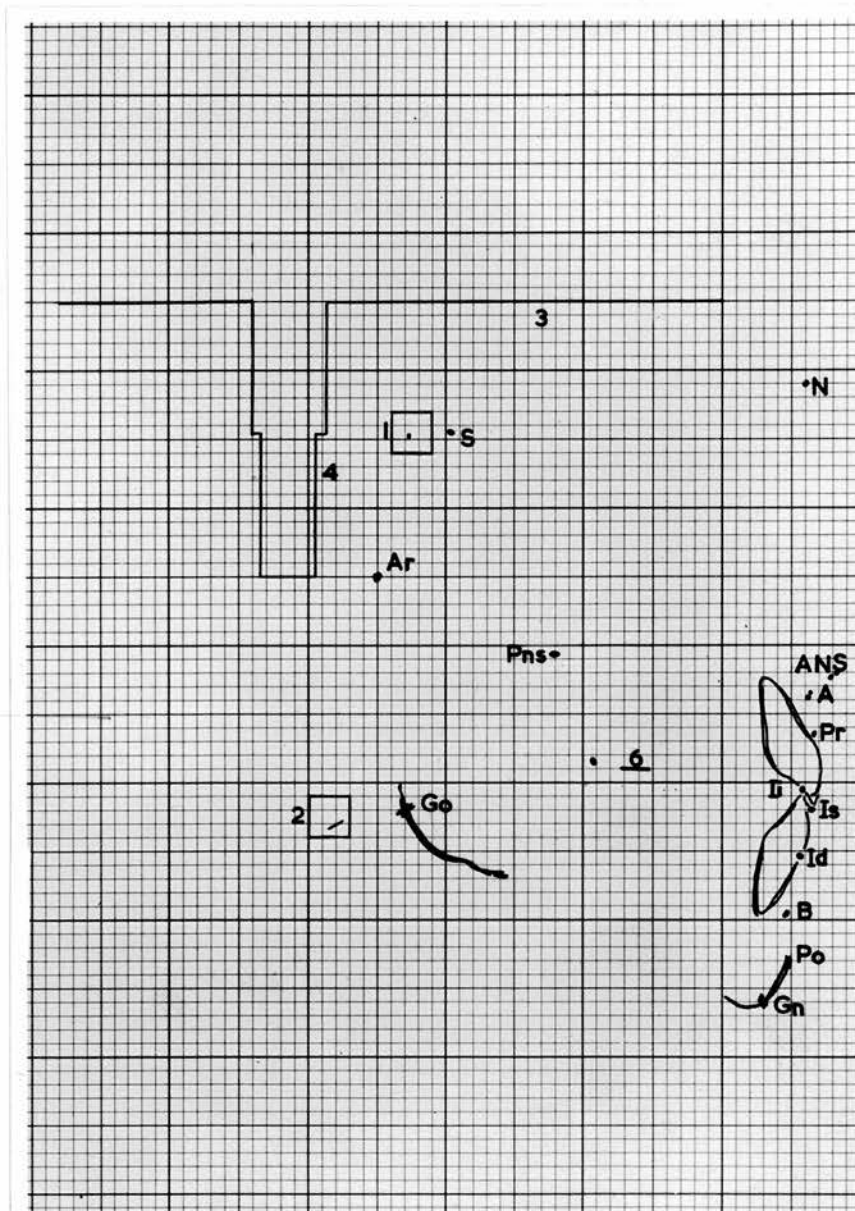


FIG. 4.

FIG. 4. Photograph of superimposition of five tracings of the same individual to show the degree of variation in the identification of anatomical landmarks. For description of method see text. (1) and (2) single dot and dash for comparison with multiple registrations. (3) and (4) Horizontal and vertical registration lines.

be made of the variations found in remeasuring the same tracing as this factor will of course be present in check tracings and a knowledge of its extent will assist in evaluating the variations arising from retracing.

3. Errors of Measurement.

Nine cases were remeasured and the results tabulated in the appendix.¹ If done with care, one would not expect when measuring the distance between two pencil dots, to find a variation in measurement much greater than the sum of the width of the dots, or where the dot is on a line greater than the width of the line. An examination of the results shows that the maximum in linear measurement variation was 0.5mm. Variation in angular measurement never exceeded 0.5° except in one instance when it was 1° .

In retracing the same X-ray slightly greater variation in measurement was found. The greatest variations in linear measurements in individual cases of different tracing from single X-rays occurred in maxillary length ANS-PNS and were differences of 2.3 and 1.9mm. (reading Linear 7 cases 3, 4.) but in general variations tended to be below 1.0mm. Angular variations ranged from nil to 2.5° . The greatest variation being found in the incisal angles and angles involving the occlusal plane. The incisal angles varied up to 1.5° and whilst this has to be considered when comparing one case with another, it

¹ Section IV.

does not detract from the validity of observed changes of an axial inclination in the same patient as the accepted practice was followed in the serial studies of transferring the axial line drawn through the incisor on the original tracing to subsequent tracings.

The variation mentioned of 2.5° occurred in case 6 angular reading 18 (occlusal plane to maxillary plane), this was associated with a variation of 2.0° in the relation of the occlusal plane to the S-N line. One further source of error must be mentioned and this is a misreading of the calipers or protractor. The time involved in remeasuring on a separate occasion the 22000 (approx.) measurements involved in this one part of the study alone rendered this impracticable. The procedure adopted was to read the instrument, record the measurements and re-read the instrument. This was not infallible as on occasion the same misreading was made. A further check was that many readings followed each other in steps and a misreading was immediately obvious. A few major errors were detected when the same reading for each individual was tabulated in columns for statistical purposes and in a few instances values which were obviously incorrect, were found to be due to transcribing errors or to reading in the wrong direction on the protractor. As a final check all maximum and

minimum values for each reading were rechecked on the tracing.

Whilst every practical effort has been made to eliminate error, one must assume that some chance errors remain undetected but one is advised that statistically if the sample is large enough these errors will tend to cancel each other and one can only conclude this section by quoting Hatton and Grainger (1958), whose main conclusion after investigating the reliability of measurements from cephalograms at the Burlington Orthodontic Research Centre is that:-

"It was found that by far the greatest source of distribution variation is due to real differences between children and that from the point of view of economical production of data for creating norms and permitting comparisons, the best experimental procedure is to use a sufficient number of children rather than attempt to reduce technical error further by duplicating measurements."

Method of superimposition of serial tracings.

The two most frequently used planes of superimposition used to study growth and treatment changes in serial roentgenographic cephalometry, are the Bolton plane of Broadbent (1937) and the sella-nasion line of Brodie (1941). The Bolton plane was not used because of the difficulty met with in locating the Bolton point. The sella-nasion line was employed as the base line in all the original tracings in this study and later modified in the study of the serial tracings in the following manner:- The sella-nasion line is drawn on the tracing of the first lateral skull X-ray and tracings of the second and subsequent lateral skull X-rays of the same patient are superimposed on the general outline of the anterior cranial base (De Coster's line) in the first tracing. The sella-nasion line of the first tracing is then transferred to the second tracing and point sella is marked in. Anteriorly the line may or may not pass through nasion on the second tracing. If it does not then the point of intersection of the line with the anterior surface of the frontal or nasal bone is marked and used as if it were nasion.¹ The original sella-nasion line is then used as the cranial base reference line for angular measurement registering on sella in subsequent tracing. Angular measurements made to it are therefore in the same relation to the

¹ Referred to later as "Artificial" nasion.

cranial base in all tracings. The reason for modifying the sella-nasion line originally was that its employment in some cases gave a picture of changes in the general facial pattern that were not thought to be correct. An example is shown in Plate 26.¹ The superimposition on sella-nasion with sella registered gave a picture that showed changes in the cranial base angle, the angle of the maxillary plane and the direction of maxillary growth. The maxillary change did not agree with the clinical picture or with the picture given by the direct superimposition of the maxilla. When the tracings were superimposed on the general line of the anterior cranial base the changes were more in line with other findings but nasion had moved downward. A check of other cases superimposing on the anterior cranial base line showed that in the majority of cases the line sella-nasion, when drawn on the serial tracings, continued to coincide with the original sella-nasion line, nasion moving forward on the extension of the original sella-nasion line, but in a few cases nasion moved either above or below the original sella-nasion line. A review of the relevant literature shows that Bjork (1955) stated that he found the sella-nasion line a reliable line of superimposition with nasion on successive tracings maintaining a constant relation to the original sella-nasion line.

¹ Plates 1-31 Appendix Section III.

Scott (1956) (1958) criticised nasion as an end point pointing out that it moves upwards in growth. Ford (1958) quoted Keith and Campion (1922) as having first noted this upward movement of nasion. They observed that although this upward movement is the rule for modern Europeans, in other races and ancient Europeans it may remain stationary or even move slightly downwards. De Coster (1951) first drew attention to the stability in children after the seventh year of the anterior outline of the cranial base and suggested its employment as a line of superimposition. This line is referred to subsequently as De Coster's line. Scott (1954) Maronneaud (1956) and Ford (1958) support De Coster's findings.

Marroneaud concludes that whilst no guiding marks of absolute value can be established, De Coster's line is at the moment the best orientation line available.

Hausser (1956) reports difficulty in following De Coster's line. Etter (1955) comments on the difficulty of interpretation of radiographs of the anterior cranial fossa. Muller (1959) criticises both the sella-nasion and De Coster's line and suggests superimposing on the occipital condyles and adjacent structures. Experience in tracing De Coster's line confirms the above observations as to its constancy after about 7 years and as to the difficulty on occasion in tracing it.

Minor variations were seen in serial tracings of the mixed dentition and permanent dentition cases but they were negligible compared with the differences seen in the serial studies of the deciduous dentition cases, as is seen in Fig. 25, Appendix Section I.

Tracing the tracings for reproduction combined with the reduction of scale in photographic reproduction tends to iron out minor variations and the illustrations give an impression of greater concordance than actually exists.

As this work was being completed Moore (1959) independently of De Coster reported his adoption of the anterior cranial base area for purposes of superimposition using both the line used by De Coster and the roof of the anterior cranial fossa. Moore also uses a similar technique with regard to the sella-nasion line to that evolved in this study. He observed in some cases that using this line nasion descended as had been found in the present study. In a more recent publication Stramrud (1959) advised the use of an internal cranial base reference line. In a recent paper Bjork (1958) also now notes that nasion may ascend or descend in growth in relation to the anterior cranial base.

The use of artificial nasion¹ instead of true nasion in making angular measurements of changes due to growth or treatment was not found to produce any

¹See page 53.

significant differences in angular readings compared with the readings obtained by the perpendicular projection of nasion to the cranial base reference line.

The method of superimposition outlined is considered in the light of the evidence to be an improvement on the nasion-sella line in so far as it removes the variable factor of nasion and is based on an intra-cranial anatomical area which anatomical evidence shows to be relatively stable after about 7 years of age. It is of course not possible to obtain an absolutely unvarying registration area. The superimpositions shown in the deciduous cases are affected by the growth that has occurred in the anterior cranial base during the period of observation but as the same method was used in all cases the changes between cases are comparable. The lines representing the axial inclination of the upper and lower incisors were transferred from the first tracing of a case to subsequent tracings by superimposing on the outline of the incisors in the first tracing, thus removing the source of error noted when drawing in the axial inclination on repeat tracings of the same radiograph.

In the study of the growth changes in the maxilla and mandible, the maxilla was superimposed on the maxillary plane in the first tracing with PNS. registered. This was chosen as giving a better

picture of forward growth of the maxilla than that given by registering on ANS. The mandible was superimposed on a line from menton tangent to the lower border of the mandibular angle with gnathion registered. In using this superimposition it has to be remembered that mandibular growth may have a backward component (the posterior border) as well as a downward and forward one, as is shown in Plate 31. It also gives an appearance of backward movement of the incisors relative to pogonion in cases showing remodelling of the mental region. It must also be remembered when assessing relative maxillary and mandibular growth, that vertical mandibular growth has not only to provide for vertical growth of the alveolus of the horizontal ramus of the mandible itself, but also for the downward growth of the maxillary complex and for maxillary vertical alveolar growth.

Part I. Roentzenographic Cephalometric Analysis of
Mesio-occlusion.

Introduction to Part I.

Part I of this study is concerned with the investigation of the first three questions posed in the introduction. They were:-

1. Is there a specific cranio-facial pattern associated with mesio-occlusion? If not, are there various relationships and proportions of the structures involved that can combine to produce a similar occlusal picture? If this is so how do these proportions and relationships differ from those associated with neutro-occlusion?
2. Do the growth changes in cranio-facial pattern differ in mesio-occlusion from those that occur in neutro-occlusion?
3. Is there any evidence of sex differences in the cranio-facial pattern in mesio-occlusion?.

The general plan of the investigations carried out is as follows:-

I. The facial diagrams constructed from the mean linear and angular measurements for each Class III and Neutro-occlusion sex/dentitional group are compared (Page 68).

II. A comparison is made of the mean linear and angular measurements of the individual structures, e.g. cranial base, maxilla, mandible etc., in the Class III and Neutro-occlusion facial diagrams, (Page 70).

III. The Class III material is grouped according to the different combinations of the varying degrees of maxillary and mandibular prognathism. The groups so formed are examined for differences of cranio-facial pattern as measured by \pm 1SD of the mean measurements of the Neutro-occlusion samples. (Page 99) (This procedure is, for convenience, referred to in the text as "the differential analysis".)

IV. An analysis is made of the linear and angular measurements in individual cases based on the standard deviations of the mean Neutro-occlusion measurements. (Page 120).

V. An examination is made of the mean measurements of the Class III and Neutro-occlusion samples at the different dentitional ages, deciduous, mixed and permanent, for evidence of growth changes. (Page 126).

VI. The mean measurements and the results of the "differential analysis" are examined for sex differences in the Class III material. (Page 136).

Theoretically a mesial occlusion of the mandibular teeth relative to the maxillary teeth may develop in various ways. The mandible may be overdeveloped or the maxilla may be underdeveloped. The over or underdevelopment may affect the whole bone or the alveolar process only. The size both of the maxilla and of the mandible may be within the normal range of variation but the maxilla may be small in relation to the mandible. In addition, the relationships may be

affected by variations of the cranial base. A decrease in length of the anterior cranial base, to which the maxilla is attached, could result in a relative protrusion of the mandible. An increased flexure of the cranial base could result in a protrusion of the mandible through a more forward positioning of the temporo-mandibular articulation. A similar effect may also be produced by a decrease in length of the posterior cranial base. (S-Ar)

In analysing the cranio-facial pattern in mesio-occlusion it is necessary therefore to consider the dimensions of the maxilla, the mandible and the cranial base and their relationships to each other.

In the maxilla the principal dimension to consider is that of antero-posterior length. The mandible is more complex, the overall length from the head of the condyle to the chin point being affected by variations in the length of the body and of the ramus and in the size of the mandibular angle. Thus with the same vertical and horizontal dimensions, an increase in the mandibular angle will increase the overall length. Similar considerations apply to the cranial base whose overall length may be altered by variations in length of the anterior or posterior parts or in the size of the angle.

The antero-posterior relationship of the maxilla to mandible is described in terms of the degree of prognathism of each jaw in relation to the profile.

As a result of the investigations enumerated on

Page 62, it will be shown that all the above factors may be present in varying combinations and degrees in the cranio-facial patterns found in mesio-occlusion.

It will further be shown that there are three main cranio-facial patterns in mesio-occlusion. As regards the individual factors associated with mesio-occlusion, it has not been possible to evaluate with precision either the relative importance of the various factors or the effects upon the facial pattern of their mutual interaction. It will also be shown that a characteristic of the growth pattern in Class III is a greater than normal increase in mandibular prognathism relative to maxillary. Finally it will be shown that apart from size there are no sex differences in the Class III cranio-facial pattern.

Method.

The linear and angular measurements described earlier were determined for each individual in the Class III and Neutro-occlusion groups. The mean, standard error of the mean, the standard deviation, maximum and minimum values and the range for each measurement were calculated and the findings for each dentitional group (deciduous, mixed, permanent dentition) male and female, in both the Class III and Neutro-occlusion were tabulated. (Appendix)

Facial diagrams were constructed for each of the groups from the mean linear and angular values, Figs. 5, 6 and 7.¹ The Class III group diagrams were each compared with their corresponding control group

¹ These and subsequent figures are in the appendix.

diagram by superimposition. The Sella-Nasion line was used as the base line with Sella registered, Figs. 8, 9 and 10. The positions and axial inclinations of the maxillary and mandibular central incisors being represented by their long axes projected to the S-N line and the mandibular plane (Go-Gn) respectively.

In comparing the means of the linear and angular measurements of the Class III material with the controls, the general picture is first examined and then the three main anatomical structures, the cranial base, the maxilla and mandible, are compared individually. Following a comparison of face height the angular relationships of the maxilla and mandible to the cranial base and each other are compared. The incisal angulations and relationships are next considered and then the other various angular relationships of the parts to each other are compared.

The mean linear and angular measurements of the individual components of the facial diagrams to be considered:- cranial base, maxilla, mandible, face height etc., have been abstracted from the main statistical data in the appendix and set out in individual tables which for ease of reference have also been placed in the appendix (Tables 4-19). It will be seen that not all the measurements in the main data are discussed. This is because some of the measurements were primarily included to assist in the construction of the mean facial diagrams.

The significance of differences between the Class III and Neutro-occlusion means was assessed by means of the "t" test, (Snedecor 1956). "t" is obtained by the formula:-

$$t = \frac{\text{Difference between sample means}}{\text{Standard error of the difference between means (S.E.diff.)}}$$

$$\text{S.E. diff.} = \sqrt{SE_1^2 + SE_2^2}$$

$$t = \frac{M_1 - M_2}{\sqrt{SE_1^2 + SE_2^2}}$$

where M_1 and M_2 are the means under comparison and SE_1 and SE_2 are their standard errors. The level of significance accepted was at the 5% level represented by a "t" value of 2.0. The omission of a "t" value in the tables for any pair of mean values indicates an absence of any significant difference between the means in question.

When comparing the facial diagrams and in the comparisons of individual dimensions that follow, allowance has to be made for the small size of the deciduous dentition groups and of the male permanent Neutro-occlusion group. An additional factor to take into account is the distribution of the age groups in the samples. This is important in the comparisons of linear dimensions in the female deciduous and male permanent groups in which the average ages of the Class III groups are 5.5 and 16.5 years, as against 4.5 and 13.5 years in the Neutro-occlusion groups. Larger

linear dimensions can be expected in the older subjects and these may be sufficient, when compared with those of the younger subjects, to conceal any trend to a smaller measurement and exaggerate any trend to a larger measurement in the Class III groups. Although this impairs the usefulness of these groups in the present study, it does underline the importance of knowing the age distribution in groups in a sample. This fact is often absent in published data. It also emphasises the importance in cephalometric studies of having comparable groups in respect of growth and development.

Results.

I. Comparison of the Mean Class III Facial Diagrams with the Corresponding Neutro-occlusion Facial Diagrams.

The superimposition of the facial diagrams shows that in Class III the maxilla is retruded and the mandible is protruded. The retrusion of the maxilla is associated with a shorter anterior cranial base length (sella-nasion) except in the female deciduous and male permanent Class III. The probable reason for this has been referred to. The protrusion of the mandible is associated with a smaller cranial base angle (\angle Nasion-sella-articulare) in all groups.

When allowance is made for the "weighting" of the Class III linear dimensions in the female deciduous

and male permanent groups. Facial height behaves differently in the permanent dentition groups to the remaining groups.

In the permanent dentition face height is greater in the Class III, while in the deciduous and mixed dentitions, Class III face height is less than in the Neutro-occlusion groups. A reverse overjet and reverse overbite of the incisors in the Class III is common to all groups and the maxillary incisors in general are more proclined in Class III, while the mandibular incisors are more retroclined.

Discussion.

In the theoretical consideration of the nature of mesio-occlusion, the principal factors that were considered to be productive of mesio-occlusion were variations in the dimensions of the maxilla, the mandible and the cranial base and in the relative antero-posterior positions of the maxilla and mandible. The comparison of these diagrams suggests that the above factors are indeed involved in mesio-occlusion, so a more detailed comparison of the components of the facial diagrams is required to ascertain the sites of significant differences between the Class III and the controls.

The difference in mean facial height between the permanent dentition and the younger groups is unexpected and indicates the presence of different facial patterns within the Class III groups. These may be the result of growth in the period between the mixed and permanent

dentitions, or may be due to the existence of two distinct Class III cranio-facial patterns, one of which happens to predominate in the mixed dentition samples and the other in the permanent dentition samples. This question is considered further in the "differential analysis."

II. Comparison of Class III and Neutro-occlusion Mean Linear and Angular Measurement.

Having shown a difference between the Class III and Neutro-occlusion facial diagrams by simple superimposition, the individual components of the facial diagram and their relationships to each other were next compared. The differences in the mean linear and angular measurements were tested for significance using the "t" test as described. The following results were obtained:-

(In the following sections all the differences described refer to those between the Class III mal-occlusion groups and the equivalent Neutro-occlusion groups, unless otherwise stated, and are given as differences in the Class III sample groups.)

Cranial Base Fig. 11. Table 4. (Tables 4-25 will be found in appendix.)

The construction representing the cranial base was superimposed on that for the Neutro-occlusion on the Sella Nasion line with Sella registered (Fig.11) as in the comparison of the mean facial diagrams.

Results:

Cranial Base Angle (/NSAr.A1). The cranial base angle

is smaller in all the Class III groups and the difference is significant in all groups except in the permanent dentition where the difference between the female groups is 2.2° ($t=1.91$) and between the male groups is 0.8° ($t=0.40$). The Class III means are however the same in both sexes (122.8°) and the absence of any indication of a significant difference in the male groups is probably associated with the small size of the permanent Neutro-occlusion sample.

Linear Dimensions.

The Anterior Cranial Base length (N-S, L1.) shows a significant difference between the Class III and Neutro-occlusion in the female mixed dentition only, where the Class III mean is smaller $t=3.4$. The posterior cranial base length (S-Ar, L2) is significantly smaller in the female mixed and permanent dentition Class III $t = 4.4$ and 3.9 . Overall cranial base length (Ar-N, L3) tends to be less in Class III and shows significant differences in the female and male mixed dentition and female permanent dentition groups, $t = 5.3, 3.31$ and 3.80 respectively. When allowance is made for the factor referred to earlier affecting linear dimensions in the deciduous and male permanent groups, the general trend in the cranial base is to smaller linear measurements in the Class III groups, eleven out of eighteen measurements are smaller, and of these, six showed significant differences.

Discussion.

Cranial Base Angle.

As already stated, theoretically a decreased cranial base angle could produce a mesio-occlusion through the more forward positioning of the temporomandibular articulation that could be associated with it and it is of interest to find a smaller cranial base angle one of the most consistent differences between the Class III and Neutro-occlusion.

The significantly smaller cranial base angle in Class III confirms the findings of Moss and Greenberg and others referred to in the review of the literature, of a smaller angle in mesio-occlusion. Sanborn (1954) did not find the difference significant ($t=1.7$). The reason for this may be found in the nature of his sample and will be referred to later in the discussion of "the differential analysis" of the Class III material.

Of equal interest is the apparent stability of the cranial base angle during post natal growth; there is no significant difference between the means of the Class III female groups. The male Class III groups show no significant difference between the mixed and permanent dentitions but a "t" difference of 2.04 exists between the deciduous and permanent Class III groups. It should be emphasised that in these and all the other comparisons to be made, too much weight is not attached to the presence or absence of

significant differences in either of the deciduous groups or the male permanent group because of the small number available in them.

Bjork (1947) found no significant difference between the means of the cranial base angles (saddle angle) in 12 year old boys and conscripts. A follow up serial study of the 12 year old boys (Bjork 1955) showed only minor changes in the means at 20 years as compared with 12 years, but individual alterations with increases or decreases of up to 5° were found. These changes may be related to the use of nasion as the anterior end point. The variability of this point has been discussed earlier and is referred to again in Part II. It will be shown that the serial studies of treated Class III cases confirm the picture of a relatively stable cranial base angle when the angle is formed by the junction at sella of a line from basion with the cranial base reference line. This construction eliminates any changes due to alterations in the positions of nasion or articulare. This finding agrees with the work of Moss and Greenberg (1955) who found the angle between the planes of the cribriform plate and the clivus constant in post-natal life. It suggests that Scott (1958) may be correct in his theory that the area where changes in the flexure of the cranial base occur is the junction of the synchondrosis between the pre-sphenoid and post-sphenoid elements of the body of the sphenoid bone,

which he says, persists in man only until birth. It would appear therefore that if the skeletal morphology producing a Class III malocclusion is determined by the flexure of the cranial base then the cause of the malocclusion must be sought in genetic or environmental factors which determined cranial base form before birth.

Linear Dimensions.

The finding of significant differences in both anterior and posterior cranial base lengths in the female mixed dentition, suggests that the size as well as the flexure of the sphenoid bone may be an important factor in the production of mesio-occlusion, since the basi-sphenoid, which forms the central portion of the cranial base, is involved in increases in both anterior and posterior cranial base lengths through growth at the spheno-occipital and spheno-ethmoidal synchondroses. Deficiency of cartilaginous growth at the synchondroses will of course also affect the length of the basi-occipital and ethmoidal sections of the cranial base. A lack of anterior growth will result in a less forward position of the maxilla, whilst a lack of posterior growth will to some degree affect mandibular position, since the posterior movement of the temporo-mandibular joint will be less than normal. These observations on the cranial base length cannot however be regarded as conclusive because of the unsatisfactory nature of the points articulare and nasion, both of which are only approximations to the

anterior and posterior ends of the base, the foramen caecum and basion. A smaller posterior cranial base length can be regarded as indicating a more anterior position of the temporo-mandibular articulation than normal relative to the anterior cranial base and the maxilla.

Overall Length.

Since the overall length (Ar-N) of the cranial base may be shortened by a reduction in the cranial base angle or by decreases in length of the anterior or posterior sections, a more significant reduction can be expected and is found in the overall length, than in that of its individual components.

Maxilla Fig. 12. Table 5. (ANS-PNS L7)

The mean diagrams of the maxillae in the Class III groups were superimposed along the line joining ANS-PNS - the maxillary plane - with PNS registered. The results show the mean maxillary lengths to be less in all groups except in the deciduous female and permanent male groups. The differences were significant in the female and male mixed, and in the female permanent dentitions, "t" values being 2.3, 4.2 and 2.3 respectively.

The experimental measurement of maxillary length PNS-A' referred to earlier, varied directly as PNS-ANS, and was significantly different in the female mixed ($t = 3.4$) and permanent ($t = 3.4$) groups but the means of the male mixed dentition group showed no significant difference. The reason for this is not understood, but statistically appears to be related to the mean

value for PNS-A' in the Neutro-occlusion male mixed group, which shows a standard error of the mean and a standard deviation more than twice that for PNS-ANS.

Discussion.

The finding of a smaller mean maxillary length in the major groups (female and male mixed and female permanent groups) agrees with previous observations cited in the review of the literature. The superimposition of the maxillae however, brings out the fact that the reduced degree of maxillary prognathism is not solely due to a reduction in length of the maxilla. The antero-posterior discrepancy in the alveolar profiles is far less than is apparent in the superimposition of the whole facial diagrams in which the position of the maxilla is influenced by the reduction in length of the anterior cranial base in Class III. Maxillary height is discussed as a component of facial height.

Mandible Fig. 13. Table 6.

The mean diagrams for the mandible were superimposed on the mandibular plane (line Go-Gn) with Go registered. The mean horizontal length (Go-Gn) was greater in all Class III groups, and was markedly so in the female deciduous and male permanent dentitions, for the same reasons that affected linear dimensions in the cranial base. (Page 67) The differences were significant in the female $t = 2.8$ and male permanent dentition, $t = 2.8$. Vertical height (Ar-Go) showed little difference between the groups for mean values,

only the male permanent groups showing a significant difference, $t = 3.00$. Mean overall length Ar-Gn was greater in all the Class III groups showing a significant difference in the female ($t = 2.3$) and male, ($t = 3.5$) permanent groups.

The mandibular angle (\angle ArGoGn) whilst greater in all Class III groups,¹ showed no significant differences, only the female permanent group approaching significance with a "t" value of 1.9.

Discussion.

The review of the literature showed most of the previous workers have found increased mandibular dimensions a factor in mesio-occlusion and it is therefore surprising to find that although the Class III means were generally larger, there were no significant differences between the means for any measurement in the deciduous and mixed dentition groups. It must however be remembered that the majority of observers based their conclusions on a simple comparison of means and did not test the mean differences for significance. Of those who did, Sanborn also found no significant difference in the vertical and horizontal length of the mandible.

These findings taken in conjunction with the figures for the cranial base and maxilla, suggest that although there is a trend to increased mandibular linear dimensions in the younger patients, cranial base and maxillary factors are of greater importance at

¹Except in the female deciduous group.

these ages. The clinical appearance of an enlarged mandible may be relative rather than absolute. The change from a trend in the mixed dentition to significant differences in linear dimensions in the permanent dentition indicates an increase in adverse mandibular dimensions with age, which accords with clinical experience. A comparison of maxillary/mandibular lengths in the different dentitional groups is made in the next section.

Even more surprising than the absence of significant differences in the majority of the linear mandibular measurements, was the absence of any significant difference in the means for the mandibular angle.

An obtuse mandibular angle has been regarded almost as a pathognomic sign of mesio-occlusion. Sanborn (op. cit.) found a markedly significant difference with a Class III mean of 133.6° , compared with 123.0° for his normal occlusion and "t" value of 8.17. The reasons for the conflict between the present findings and those of previous investigations may be twofold. Firstly to judge by many of the standard texts, a mesio-occlusion which does not show an obtuse angled mandible was not regarded as a true Class III. The cause of the mesio-occlusion in these, so called "false" Class III, cases was sought in environmental factors such as enlarged tonsils or protrusive habits instead of in the basic skeletal morphology. Therefore, since an obtuse angle was

regarded as a sine qua non of mesio-occlusion, it is not surprising that a large mandibular angle was a consistent finding in earlier investigations.

Secondly, in the writer's opinion, there is a type of mesio-occlusion characterised by a small mandibular angle and many such are included in the present study. It is probable that the mean figure for the mandibular angle has been influenced by the inclusion of the small angle cases which will have counter balanced the cases with a large mandibular angle. (The mean of the minimum values of the mandibular angle for each Class III group was 120.3° and that of the maximum values was 140.6° . The corresponding figures for the Neutro-occlusion groups were 120.0° and 135° respectively.)

It is not the obtuse angle which is the cause of the mesio-occlusion but the adverse factors associated with it, such as a reduced maxillary length, as will be shown later in the "differential analysis" of mesio-occlusal skeletal patterns. For a given horizontal length, an increase of the mandibular angle will decrease mandibular prognathism, but will increase the facial height. A reduction in the mandibular angle has the opposite effect, mandibular prognathism increased and face height decreased.

Comparisons of Maxillary and Mandibular Lengths.

The relative length of the maxilla to the mandible has been stressed earlier as an important factor. In the following table the mean maxillary lengths in the

Class III and Neutro occlusion groups are expressed as percentages of the overall mandibular lengths in each group.

Table 7.¹

ANS-PNS (L7) as % of Ar-Gn (L6)	Decid. Dent.		Mixed Dent.		Perm. Dent.	
	Female	Male	Female	Male	Female	Male
Neutro-occlusion	50.01%	50.4	49.7	50.2	48.3	48.8
Class <u>III</u>	50.2	48.7	46.04	47.1	45.6	45.4

In both groups maxillary length as a percentage mandibular length shows a decrease between the deciduous and the mixed dentition and between the latter and the permanent dentition. This is more strongly marked in the Class III group. This suggests a greater relative growth of the mandible in both Neutro-occlusion and Class III. (In part II, the study of serial tracings of treated cases which relapsed shows the relapse to be due to a continuing mandibular growth with little or no maxillary growth.)

Because of the small size of the deciduous dentition group, too much cannot be inferred from the difference between these and the mixed dentition groups. The control group shows little change over this period compared with the Class III group which shows a more marked trend to a decrease in maxillary length relative to mandibular. This may be related to the quite marked change in the profile of the symphysis observed in some children, which is described in the

¹Also given in the appendix.

serial study of treated Class III deciduous dentition cases in Part II. This has also been observed by Meredith (1957) in a serial study of 34 children from 4 to 14 years of age.

Comparison of the Antero-posterior Position of the Maxillary First Permanent Molar in Class III and Neutro-occlusion Cases. Table 8.

The antero-posterior position of the first permanent molar in the maxilla was assumed constant by Angle and he founded his occlusal classification upon it, (Angle 1889). This assumption is not accepted today and if a more distal position of the upper first molars could be shown in Class III cases it could account for a Class III malocclusion in the presence of a normal basal bone relationships of maxilla to mandible.

Schoenwetter (1948) found the position of the upper first molar more mesial in Class III than in Class I and Class II malocclusions. His findings however were based on small mean differences which he had not tested for significance, nor was it possible to do so with the data given by him.

The position of the first molar has been determined by measuring the distance PNS' -6 (L9), i.e., from the tip of the disto-buccal cusp of the first molar, (mesial cusp of 2nd molar if the first is absent) to PNS', (the point on the occlusal plane where a perpendicular from PNS meets the occlusal plane).

The fact that in some cases in the permanent dentition group the mesial cusp of the second molar has been used in the absence of the first molar is not thought to be of significance partly because such cases were few and partly because following the loss of the first molar the second molar usually moves mesially a sufficient amount to make the two points comparable.

There is no significant difference in the antero-posterior position in the maxillary arch of the first permanent molar in either the Class III or the Neutro-occlusion groups except in the male permanent where there is a significant difference ($t = 2.1$) between the Class III group and Neutro-occlusion. The distance from 6 to PNS' is greater in the Class III group. This is probably due to the older age groups in this sample in whom the increase in maxillary length to accommodate the third molars will have taken place.

Facial Height. Table 9.

Facial height is divided into upper face height - Nasion-Anterior Nasal Spine - and Lower face height - Anterior Nasal Spine-Gnathion. Lower face height is subdivided into maxillary height and mandibular height which in this study are represented by the distance ANS to the occlusal plane and gnathion to the occlusal plane respectively.

Total Face Height N-ANS-Gn (L10 + L17).

There is no significant difference between the means of the Class III and Neutro-occlusion groups except in the female mixed dentition where the Class III total face height is significantly less, $t = 3.6$.

Upper Face Height N-ANS. (L10)

There is no significant difference between the means of any of the groups.

Lower Face Height ANS-Gn. (L17).

The only significant difference between the means is, as in total face height, in the female mixed dentition where the Class III mean is less, $t = 3.5$.

Maxillary Face Height ANS-OP' (L18).

Significant differences occur only in the mixed dentition where the male and female Class III means ($t = 4.04$ and 2.05 respectively) are less than the Neutro-occlusion.

This points to a reduction in the maxillary face height being the explanation of the significant differences found in total face height and lower face

height in the female mixed dentition Class III group. A similar trend is present in the means for the male mixed dentition Class III but only reaches significance in maxillary face height.

Mandibular Face Height OP-Gn. (L19).

The female permanent dentition group is the only one to show a significant difference between the means, the Class III being the greater $t = 2.39$. The male Class III ($t = 1.8$) shows the same trend which is a reversal of the trend in the mixed dentition in which the Class III means are less than those of the Neutro-occlusion groups.

Anterior Mandibular Height. Li-MnP. (L21).

The previous measurement of mandibular face height represents the contribution of the mandible to lower face height when the teeth are in occlusion and can be regarded as anterior mandibular height less the amount of the incisal overbite. The present measurement from the tip of the lower central incisor to the mandibular plane can be regarded as a measure of anterior mandibular height uninfluenced by the degree of overbite. The means show no significant difference and in contrast with the previous measurement, the Class III female permanent group, instead of being significantly greater, shows a mean (38.49) less than that of the Neutro-occlusion (39.25).

Discussion.

Facial height is affected by the mandibular angle, a large angle lengthening and a small angle decreasing

the height of the face. The absence of any significant differences for total face height, except in the female mixed dentition, is probably due to the presence in the samples of two contrasting facial patterns, one with a larger than, and the other with a smaller than normal mandibular angle. The finding of a significant difference in maxillary height in the mixed dentition only, may be due to growth taking place between the mixed and permanent dentitions, or to the small mandibular angle type of Class III being more common in the mixed dentition than the high angle type. This is analysed further in the "differential analysis" of the Class III material. The absence of any significant difference in upper face height (N-ANS) in Class III, shows that vertical growth of the maxillary complex above the floor of the nose does not differ from normal.

This observation is not however wholly supported by the results of the "differential analysis" where it will be shown that there is evidence indicating a reduction in upper face height in the Class III group, associated with a small mandibular angle.

The difference between the results for mandibular face height (OP-Gn) and mandibular anterior height (Ii-MnP) in the permanent dentition is due to the lesser degree of overbite in Class III than in Neutro-occlusion in the permanent dentition. Mandibular face height (OP-Gn) as previously mentioned, is the

mandibular height less the incisor overbite, whilst mandibular anterior height is measured from the incisal edge of the lower incisor. Reference to the figures for overbite (Table 18) shows that whilst the overbite in the mixed dentition is approximately the same in both Class III and Neutro-occlusion, in the permanent dentition the Class III overbite is much reduced. This reduction with age of the Class III overbite is confirmed by clinical experience and as will be shown in the serial studies in Part II, is the result of mandibular growth.

Maxillary Prognathism. Table 10. Basal (A4) Alveolar (A6).

The differences between the means for basal (\angle SNA) maxillary prognathism show a common trend, the Class III mean being less in all groups but the difference between the means only reaches significance in the female permanent group, ($t=2.78$). Alveolar (\angle SNPr) prognathism shows, generally, a similar picture with a significant difference again in the female permanent group, ($t=2.59$). There is however little difference in the means of the other female groups.

Discussion.

The general picture of a lesser degree of maxillary prognathism in Class III suggests that the Class III samples include a greater number of patients with a less than average degree of maxillary prognathism. The lack of significant differences in the mixed and deciduous dentition groups suggest that

maxillary retrognathism, whilst undoubtedly a factor in some cases, is not a major factor in the majority of cases. The reason for the significant differences between the means for basal and alveolar prognathism in the female permanent groups and the greater differences between the means in the male permanent groups than in the mixed dentition, is not clear. In the study of treated cases in Part II relapses will be shown to occur in older patients because of an increased forward mandibular growth without corresponding forward maxillary growth. These observations may provide a clue by suggesting an earlier arrest of maxillary growth in the Class III than normal. If this view is correct the fault must lie in alveolar growth, since maxillary length, as measured by PNS-ANS, does not show any greater discrepancy in the permanent Class III groups than in the mixed dentition Class III groups.

Mandibular Prognathism. Table 11

The angles that the three points on the profile of the mandible, infradentale, Downs' point B and pogonion, form with the S-N line, \angle SNId, \angle SNB and \angle SNPo respectively, are here described as the angle of alveolar, the angle of basal alveolar, and the angle of mandibular prognathism, respectively. The means for all the angles are significantly greater in the Class III in all the mixed dentition groups with "t" values ranging from 3.13 to 6.1. The deciduous dentition Class III means are significantly greater for

all angles except for the female Class III angle of alveolar prognathism SNId, which has a "t" value of 1.9. In the permanent dentition groups, all the angles in the Class III are significantly greater except alveolar prognathism in the male "t" = 1.93 and mandibular prognathism in the female, "t" = 1.78.

Discussion:

The general picture confirms statistically the clinical observation that the mandible in profile is more prominent in Class III cases than in Neutro-occlusion cases. The difference in maxillary prognathism between the Class III and Neutro-occlusion can be explained in part by the trend to a decrease in maxillary length in Class III. The major cause of the very much greater difference in mandibular prognathism between the Class III and Neutro-occlusion in the mixed dentition, is not the increased dimensions of the mandible in Class III, as the differences between the Class III and Neutro-occlusion means are not significant. It is considered that the difference in prognathism is in the main due to the factors causing a more anterior position of the mandible relative to the maxilla in Class III. These factors, as has been suggested earlier, are decreases in the cranial base angle and posterior cranial base length.

Relative Maxillary Mandibular Prognathism. Table 12.

This is a key relationship in determining the antero-posterior relationship of the teeth and in clinical practice is assessed by determining the

difference between the maxillary angle SNA and the mandibular angle SNB, the figure obtained being referred to as the A/B difference, which is positive if SNA is the larger angle, and negative if SNB is the larger.

In what is known as the "Skeletal Classification", the antero-posterior basal bone relationships of maxilla and mandible are classed as Skeletal Class I, II or III, depending on the SNA-SNB difference as follows:-

Skeletal Class I or Normal A/P relationships.

A/B difference $+2^{\circ}$ to $+4^{\circ}$

Skeletal Class II Mandible distal to maxilla.

A/B difference $+5^{\circ}$ and more.

Skeletal Class III Mandible mesial to maxilla.

A/B difference $+2^{\circ}$ and less.

Table 12 shows the mean SNA-SNB values and differences for the Class III and Neutro-occlusion.

Discussion.

It will be seen that in the Neutro-occlusion groups, the A/B difference is always positive whilst in the Class III group it is negative in all groups except the female deciduous where the difference is $+1.17^{\circ}$ but is still within the Skeletal Class III range. It should be made clear that the Skeletal Classes I, II and III are not equivalent to Angle's three classes of malocclusion.

Generally speaking Skeletal Classes II and III

are usually associated with Angles Class II and Class III malocclusions, but a Skeletal Class I may be associated with a normal occlusion or any of the Angle Classes of Malocclusion.

Angle of Convexity (Downs). Table 13. (Fig. 3A).

This measures the relative protrusion of the maxilla at Point A to the mandible at pogonion. It also gives an indication of the shape of the profile, a positive value indicating a convex, and a negative value, a concave profile. A value of "0" is obtained when N, A, and Po, are in a straight line, indicating a vertical profile. The Class III values are positive in the deciduous and negative in the other groups and the Neutro-occlusion values are all positive with significant differences between the means of the Class III and Neutro-occlusion in all groups.

While the standard deviations show that Class III cases may have a positive angle of convexity, a negative value is characteristic and increases with age.

Incisal Angulation. Table 14.

Maxillary Incisor. (Axial inclination to S-N, A12)

The Class III means are all larger than the corresponding Neutro-occlusion means but significant differences are present only in the female deciduous ($t = 2.0$) and mixed dentitions ($t = 3.3$).

Mandibular Incisor. (Axial inclination to MnP, A13).

The Class III means, except for the female deciduous, are all smaller than those of the Neutro-

-occlusion groups, significant differences occurring in the male mixed dentition ($t = 2.08$) and male permanent dentition ($t = 2.35$) and female ($t = 3.68$).

Inter-incisal angle.

There were no significant differences between the means for any of the groups.

Discussion.

An increased proclination of the maxillary incisors and increased retroclination of the mandibular incisors has been noted by several writers. Noyes et al, Bjork, Sanborn and Jean (op. cit.), Maj et al. (1958), found the upper incisal angulation to be within the range of normal but the lower incisors were retroclinated. In the present study significant differences between the Class III and Neutro-occlusion means for both upper and lower incisal angulations were not found in any one group. The small means of the angles for both upper and lower deciduous incisors in the female deciduous Neutro-occlusion group are due to the inclusion in the five cases of a child with marked retroclination of both upper and lower incisors.

The lack of any significant difference in the interincisal angle is due to the proclination of the upper incisors being compensated by the retroclination of the lower incisors. The effect upon the overjet of the incisal angulations is to counteract the trend to an increased reverse overjet resulting from the differences in basal prognathism.

Angulation of Planes to the Anterior Cranial Base.Table 15.Maxillary Plane. (A17).

There are no significant differences between the means in any of the groups.

Mandibular Plane. (A11).

There is a significant difference between the means of the Class III and Neutro-occlusion female mixed dentition groups but not between any of the others. The Class III mean is smaller ($t = 3.98$).

Occlusal Plane. (A10).

The angle of the occlusal plane with the cranial base is only significantly smaller in the deciduous dentition groups (male $t = 2.41$, and female $t = 2.0$) and in the female mixed dentition groups, ($t = 3.14$).

Discussion.

The lack of significant difference in the angle made by the maxillary plane and the anterior cranial base in any of the groups implies that the anterior and posterior vertical growth of the maxilla above the maxillary plane and the mid line nasal structures associated with it maintain similar proportions in both Class III and Neutro-occlusions. A vertical growth at one or other end of the maxilla would tilt the plane. This balance of growth together with the absence of any significant difference in the linear height, N-ANS, suggests that in the vertical plane this part of the maxilla does not differ from normal. An

exception to this occurs in the small mandibular angle Class III type, as will be described later. In the classical type of Class III with a large mandibular angle, the mandibular plane forms a larger than normal angle with the cranial base. The same observations that were made regarding the different Class III types (Pages 78-9) when discussing the mandibular angle, apply to the figures for the mandibular plane angle.

The finding of a significantly smaller angle between the mandibular plane and the cranial base in the female mixed dentition is related to the reduced face height. Since the mandibular plane angle varies with the mandibular angle and a small mandibular angle decreases face height, the small mandibular plane angle supports the view expressed earlier that it is probable that the Class III pattern characterised by a low mandibular angle is more common in this sample than the large angle type and this is confirmed in the "differential analysis."

The significant difference found in the female mixed dentition for the occlusal plane angle shows the same trend as that for the mandibular plane and is associated with the reduced anterior maxillary height ANS-OP'. The angle of the occlusal plane is dependant on the relative vertical positions of the distal cusp of the maxillary first permanent molar and the central incisor tip. Since there is no significant difference in the vertical distance of

the molar cusp from the maxillary plane in the Class III and Neutro-occlusion mixed dentition female groups, the smaller occlusal plane angle in the Class III cases must be due to the smaller anterior maxillary height found in this group. (The vertical distance of the molar cusps from the maxillary plane is approximated by the distance PNS-PNS' where PNS' is the point of intersection of a perpendicular from PNS to the occlusal plane. The means for this distance, 16.85 ± 0.87 (Neutro) and 16.59 ± 0.29 (Class III), show no significant difference.)

Y Axis Table 16. (/NSGn A15).

Class III means are smaller than the Neutro-occlusion in all groups, but the differences between the means are significant only in the mixed dentition where "t" values of 4.58 and 2.69 were obtained for the female and male groups.

Discussion.

The so called Y Axis has been used in roentgenographic cephalometric studies to express the resultant of the downward and forward growth of the face, but Dixon (1959), in a recent study, has found that it does not accurately reflect the direction of facial growth and in this study it is used chiefly to show changes in mandibular position and in the direction of mandibular growth in the serial studies of treated cases.

The angle of the Y Axis varies directly with the mandibular angle. It is decreased by an increase in

the horizontal length of the mandible. The presence of significantly smaller values for the Y Axis in the mixed dentition, but not in the permanent dentition, is probably related to the presence in the mixed dentition of the cases with a small mandibular angle. As will be shown in the "differential analysis", these cases tend to show an increased horizontal length.

In the mixed dentition the overbite (Table 18) tends to be greater than in either the deciduous or permanent dentition. This suggests a greater amount of closure in the mixed dentition with the chin travelling farther upwards and forwards which will also reduce the angle of the Y Axis. A further factor may be the smaller anterior maxillary height found in the mixed dentition group.

Chin Angle (Bjork) Table 17. (A19).

The chin angle, described by Bjork (1947), is formed by the intersection of a line joining infra-dentale and pogonion with the mandibular plane. It is a measure both of mental prominence and incisal retroclination, the more prominent the chin and the more retroclinated the mandibular incisor, the smaller is the chin angle. Table 17 shows a significant difference only in the female permanent group where the Class III group is significantly smaller, "t" = 3.10. In the other groups the means are smaller in the deciduous dentition, the mean difference approaching significance in the male group.

but in the mixed dentition there is little difference, the means, contrary to expectation, being fractionally larger in the Class III groups.

Discussion.

This does not appear to be a measurement of crucial significance, the incisal angulation and prominence of the mental region being more directly determined as has been described.

Overjet. Table 18. (L24)

A mean negative or reverse overjet is present in all the Class III groups, each group differs significantly from the Neutro-occlusion group. A reverse overjet is of course a prominent but not essential occlusal feature of mesio-occlusion and therefore forms part of the problem being studied. (There were 11 cases with mesio-occlusion and a normal overjet and overbite. Such a case is illustrated in Plate 29.)

Overbite. Table 18. (L23).

Overbite has been discussed in its relationship to the mandibular height as determined by OP-Gn in which measurement the overbite of the lower incisor is, as it were, deducted. There is no significant difference in any of the groups between Class III and Neutro-occlusion. As already noted a comparison of the mean values of the overbite in the mixed and permanent Class III groups shows a trend to a reduction in this measurement in the permanent dentition, particularly in the male groups. The

reduction of the overbite in individual cases is illustrated in the serial studies in Part II.

Conclusions.

The conclusions which can be drawn from the comparisons made of the mean linear and angular measurements may be listed as follows:-

1. The cranial base dimensions in general and the cranial base angle in particular are important factors in the production of mesio-occlusion. (It is assumed that the increased flexure, or more correctly, the decreased straightening out of the cranial base, results in the temporo-mandibular fossa being in a more anterior position relative to the maxilla. It is also assumed that a decrease in posterior length as defined in this study by Ar-S, indicates a more forward position of the fossa and hence of the mandible relative to the maxilla.)
2. A constant factor is a tendency to a decrease in maxillary length associated with a tendency to an increase in mandibular length creating a disproportion between them. The change from a trend to a significant difference with increasing age implies that mesio-occlusion may be a progressive condition which worsens with growth and development.
3. The lack of significant differences in the mandibular angle between the Class III and Neutro-occlusion is the main difference from the previously published findings of mandibular dimensions. It is

skin to the conflicting findings in the mixed and permanent dentitions regarding facial height. Both can be explained by postulating the presence of contrasting facial patterns within the samples. The "differential analysis" described in the following section will show evidence confirming this hypothesis.

4. The significant differences observed between the Class III and Neutro-occlusion for maxillary and mandibular prognathism, whilst characteristic, are not in themselves factors in the production of mesio-occlusion, but are the expressions of the variations in size and relationships observed in the cranial base, the maxilla and mandible.

5. The increased proclination of the maxillary incisors and retroclination of the mandibular incisors have a compensating effect and tend to reduce the reverse overjet produced by the jaw relationships.

6. The general direction of growth of the mandible as expressed by the Y axis is more forward in Class III than in Neutro-occlusion, while the Class III maxilla does not differ significantly in its angular relation to the cranial base from Neutro-occlusion.

III. "Differential Analysis" of the Class III Material.

The comparison of the mean values of the linear and angular measurements of the Class III and Neutro-occlusion material has indicated the average trend of the cranio-facial pattern in mesio-occlusion but it gives no indication of the way in which the many variations of size and relationships combine to produce mesio-occlusion in the individual.

In the clinical diagnosis of mesio-occlusion, a differential diagnosis is made on the basis of a subjective estimation of the relative development of maxilla and mandible and the case may be diagnosed in such terms as "mandibular protrusion" or "maxillary retrusion" or a combination of both. It was considered that a breakdown of the Class III material on these lines might help both to clarify further the picture as derived from the statistical analysis, particularly with regard to the mandibular angle and facial height and to test the validity of the clinical concepts of the different facial types associated with mesio-occlusion that have been formed. These fall into three main groups, "mandibular protrusion", "maxillary retrusion" and in the third group neither jaw is markedly over or under developed. In this last group the occlusal disturbance is mild but the mandible, whilst not protrusive, is more prominent in the profile than the maxilla. These are referred to as "dominant mandible" cases.

Method of "Differential Analysis."

The combinations of relationships giving rise to the relatively greater mandibular prognathism observed in the Class III cases may be due to maxillary retrognathism, mandibular prognathism, a combination of both, or an unfavourable combination of normal maxillary and mandibular prognathism. For the purpose of this analysis, an arbitrary standard of normal, which was ± 1 standard deviation of the mean values for prognathism in the Neutro-occlusion material was used. The degree of maxillary prognathism was determined by the angle SNA, and mandibular prognathism by the angle SNPo (Fig. 14). Table 20 shows the various combinations of maxillary and mandibular prognathism that were obtained and the distribution of the Class III cases among them. The Class III cases fell into three main groups:-

	Maxilla \angle SNA	Mandible \angle SNPo
1.	Within range ± 1 SD	Within range ± 1 SD, Group A.
2.	" " ± 1 SD	Greater than ± 1 SD, Group B.
3.	Less than $- 1$ SD	Within range ± 1 SD, Group C.

Shown diagrammatically in Fig. 14.

These three groups accounted for 217 of the 226 cases. The remainder (9 cases) as they do not appear to affect the general picture, are discussed later, where they are of interest.

The Class III cases falling into each category were analysed individually in respect of the principal

linear and angular measurements, the signs "0", "+", or "-" being recorded according as to whether the measurement under consideration was within, greater than, or less than the range of $\pm 1SD$ of the mean of the Neutro-occlusion value for the corresponding sex and dentitional group to which the Class III case belonged. For example, in the 33 female mixed dentition cases falling in Group A, the findings for cranial base dimensions were as follows:-

Cranial Base	0	+	-
\angle NSAr	21	4	8
N-S	22	3	8
S-Ar	20	1	12
N-Ar	19	1	13

It will be seen for instance, that in 21 out of the 33 cases the cranial base angle was within $\pm 1SD$ of the mean cranial base angle for the female mixed dentition Neutro-occlusion sample. In four cases it was greater than $+ 1SD$ and in eight cases it was more minus than $-1SD$ of the Neutro-occlusion mean.

The number of nought, plus and minus values for each measurement in each Group A Class III dentitional group were added and the totals for each group added together to make combined totals of 0, +, - values for all the Class III cases in Group A. The combined total of 0 values was then expressed as a percentage of the joint totals of the 0, +, and - values in

Group A and similarly for the plus and minus value totals. (As each 0, +, or - represents the measurement concerned in an individual case, the combined total of 0, +, and - values gives the number of cases in Group A.) The same procedures were carried out for Groups B and C. The collective results are shown in Table 22, where it will be seen for example that of the 107 Group A cases, 63.5% had a cranial base angle within \pm 1SD (0) of the Neutro-occlusion mean, 9.4% had an angle greater than +1SD (+) and 27.1% had an angle more minus than -1SD (-).

The linear 0, + and - values in the Class III male permanent group have been excluded from the linear percentages for reasons already mentioned (Page 67) and because of their exclusion the figure representing 100% for the combined totals of linear values of "0", "+" and "-" in each group is less than the figure for 100% for the angular "0", "+" and "-" values which latter figure represents the number of the Class III cases in each of the groups A, B, C.

The number of Class III cases in each category excluding the minority groups are expressed as percentages of the whole material in Table 21.

Findings: Just under half of the Class III cases 107 or 47.7% fell into the category Maxillary and Mandibular Prognathism within \pm 1SD of Neutro-occlusion (Group A). The next largest group (Group B) contains 74 cases or 32.8%, being those cases where mandibular prognathism exceeds +1SD of Neutro-occlusion, the

maxilla being within $\pm 1SD$ of Neutro-occlusion. The third principal group (Group C), consists of those cases where maxillary prognathism is minus more than $-1SD$ and that of the mandible is within $\pm 1SD$ of Neutro-occlusion. Of the remaining categories the most adverse combination (Maxillary prognathism more minus than $-1SD$ and mandibular greater than $+1SD$) was found only in 1 case or 0.4%. There were four cases, or 1.8%, where the prognathism of both jaws exceeded $+1SD$ and three cases or 1.3% where in both jaws prognathism was more minus than $-1SD$. It is considered that these cases may be regarded as extremes at either end of the $\pm 1SD$ range. The remaining case presents a theoretically most improbable combination of maxillary prognathism greater than $+1SD$ and mandibular prognathism more minus than $-1SD$. In the illustration of this patient (Plate 29), the profile suggests disto-occlusion rather than mesio-occlusion and this indeed was the clinical impression formed on first seeing this patient. This is an extreme example of a facial pattern classified clinically as "lower alveolar protrusion" in which the basal maxillary and mandibular prognathism are usually within $\pm 1SD$. Other cases similar in profile were found to fall within Group A.

Typical cases in Groups A, B and C are shown in Plates 21 and 25. The percentage figures for the measurements in Table (22), except those for the

¹ Percentages to nearest decimal place hence apparent discrepancy in multiples of 1%.

various angles of prognathism and the Y Axis, have been set out in the form of "histograms" to illustrate the findings graphically. In a normal distribution approximately two thirds or 66.6% of a sample will fall within +1 standard deviation of the mean value of the sample (= 0 value in histogram), 16.7% or one sixth will have values more minus than -1 standard deviation (= minus value in histogram) and 16.7% or one sixth will have values greater than +1 standard deviation. (= plus value in histogram). Lines have been drawn at the 66.6% and 16.7% level for comparative purposes. The distribution of Class III values for any measurement will not of course correspond with this distribution unless they correspond approximately in mean value and range with the Neutro-occlusion figures. The results are now examined to see whether there are any differences in the distribution of the 0, + and - values in the three main groups. ie. -

Group A. Maxilla \angle SNA \pm 1SD Mandible \angle SNPo \pm 1SD

Group B. Maxilla \angle SNA \pm 1SD Mandible \angle SNPo \times + 1SD

Group C. Maxilla \angle SNA \leftarrow - 1SD Mandible \angle SNPo \pm 1SD

Cranial Base. Fig. 15 A, B.

Cranial Base (Saddle Angle) NSAr.

Group A shows an increase in minus values 27.1% at the expense of plus values. Group B is similar with marked minus values 40.5% and few plus values 1.4%. Group C shows a different picture with a

marked increase in 0 values 83.4% and decreased plus and minus values.

Anterior Length. S-N.

All three groups show a similar picture with 0 values around the 66.6% level and increased minus values at the expense of plus values.

Posterior Length. S-Ar.

Group B approximates a normal distribution with some increase in minus values. Group A shows a marked increase in minus values. Group C is similar with a greater number of minus values 42.8% and fewer "0" values 46.5%.

Overall Length. N-Ar.

Groups A and B are similar with increased minus values and decreased plus and 0 values. Group C is similar in regard to low plus values but shows a smaller increase in minus values.

Maxillary Length. PNS-ANS. Fig. 16.

In all groups 0 values are a little low with a marked increase in minus values chiefly at the expense of plus values which are nil in Group C.

Mandible. Fig. 17.

Mandibular Angle /ArGoGn. Fig. 17A.

Group A has increased 0 and plus values, Group C mainly increased plus and reduced minus values, whilst Group B differs in showing increased minus values, 23%.

Vertical Height. Ar-Go. Fig 17A.

Behaves more as a normal distribution and suggests little difference from Neutro-occlusion in any group,

only Group B showing much variation with increased 0 and reduced minus values.

Horizontal Length Go-Gn. Fig. 17B.

All groups show varying reduction in minus values. Groups A and C have an increase in 0 values whilst Group B has a marked number of plus values 37.6% at the expense mainly of 0 values.

Overall Length. Ar-Gn. Fig. 17B.

Group B shows a normal distribution, A an increase in 0 values, and C an increase in plus values.

Facial Height. Fig. 18.

Overall Height. N-Gn (N-ANS-Gn). Fig. 18A.

All the groups present a different picture. Group A has an approximately normal distribution, Group C tends to increased plus values (28.5%), whilst minus values predominate in Group B. (53.7%).

Upper Face Height N-ANS. Fig. 18A.

There is an increase in 0 values in Group C and minus values are not so marked except in Group B, (37.3%) which shows an increase mainly at the expense of plus values, (1.5%).

Lower Face Height. ANS-Gn Fig. 18B.

Shows a similar distribution to overall height with a normal trend in Group A and marked minus values in Group B (49.2%). There are also a greater number of plus values in Group C (32.1%) which contrasts with Group B.

Maxillary Face Height. ANS-OP'. Fig. 18C.

Group C has a normal distribution Group A some increase in minus values and decrease in plus values. Group B again is consistent with large minus values, (43.3%) and negligible plus values, (3.0%).

Mandibular Face Height. OP'-Gn. Fig. 18C.

A fairly normal picture in Group A, some increased minus values in Group B but much less than the increase seen in maxillary face height. Group C shows a reduced number of 0 values with an equal increase in plus and minus values, (25%).

Prognathism. Maxilla /SNA (A4) /SNPr (A6)Mandible /SNPo (A8) /SNB (A5) /SNId (A7).

The picture of prognathism in Groups A, B, and C, of course reflects the basis of the classification of the groups with 100% "0" values for SNA in Groups A and B and 100% minus values in Group C and 100% 0 values for SNPo in Groups A and C and 100% plus values in Group B. The angle of maxillary alveolar prognathism \angle SNPr reflects the values of \angle SNA. In group A, 0 values predominate whilst in Group C minus values are most frequent. Group B shows no minus values, the plus values of 16.2% can be correlated with the increased plus values for maxillary incisal inclination shown in this group. Mandibular alveolar prognathism \angle SNId similarly varies with \angle SNPo. (Mandibular basal prognathism.)

The angle of mandibular basal alveolar

prognathism \angle SNB reflects the values of \angle SNPo in groups B and C but shows an increase in plus values (26.2%) in group A. The angle of convexity \angle NAPo, a measure of relative maxillary mandibular prognathism, shows no plus values in any group. Groups B and C having 90.5% and 86.1% minus values respectively, whilst Group A again reflects the prominence of the mandible in this group with 30.8% minus values and no plus values.

Y Axis. \angle SNGn (A15).

Group A and C are similar with marked increases in 0 values 82.2% and 91.6% and corresponding marked decreases in the plus and minus values. Group B in contrast has no plus values, 19% "0", and 81% minus values.

Incisal Angles. Fig.19.

Maxillary Incisor. \angle Is/SN (A12).

Group A shows a slight increase in 0 and plus values and a decrease in minus values. Group B a marked increase in plus values (36.5%) and Group C, unexpectedly, an increase in minus values, (25.0%).

Mandibular Incisor. \angle Ii/MnP (A13).

Groups A and B have near normal 0 values with reduced plus and increased minus values. Group C shows a marked increase in minus values (47.2%) together with decreases in 0 and plus values.

Angles of Planes to Anterior Cranial Base (S-N) Fig. 20.

Mandibular Plane. \angle MnP/SN (A11).

Each group differs markedly. Group A is the

nearest to normal with slight increases in 0 and plus values. Group B has a sharp reduction in 0 values (40.5%) with plus values non-existent and a greater percentage of minus values than 0 values, (59.5%). Group C shows a marked increase in + values (41.5%) and decrease in minus values to 5.6% with 0 values down slightly.

Maxillary Plane /MxP/SN (A17).

Groups A and C are similar in trend showing increased plus and decreased minus values but differing slightly in degree, whilst B contrasts with a marked reduction in plus values (4.2%) and increase in 0 values.

Discussion.

The characteristics of the cranio-facial structures of the cases in Group A, B and C, as shown by the distribution of nought, plus and minus values for the measurements considered are now discussed for each group in turn.

Of importance from a causative viewpoint are the dimensions of the cranial base, of the maxilla and of the mandible. Facial height and its components also reflect the variations in these structures and the incisal inclinations are a measure of the adaption of the occlusion to the jaw relationships.

Group A. "Dominant Mandible." (Plates 6,8,20,21.)

The dominance of the mandible in this group is relative, there being no increase in plus values for

vertical or horizontal length, the characteristic feature is an increase in 0 values. The mandibular angle shows only a slight increase in plus values.

The cause of the relative protrusion of the mandible lies in the maxilla and cranial base. The maxillary length shows about twice the number of minus values (30.4%) compared with a normal distribution and there is an increase in minus values for maxillary height ANS-OP' which includes the alveolar bone and its underlying "basal" bone. The figures for the cranial base show marked increases in minus values including those for the cranial base angle and posterior length. A more anterior position of the temporo-mandibular fossa (and hence of the mandible) relative to the maxilla is related to a smaller than normal value for these measurements. There is some increase in minus values for anterior length suggesting a less forward position of the maxilla. The effect of all of these factors is to produce an unfavourable antero-posterior relationship of maxilla to mandible. This tendency to decrease in all the dimensions of the cranial base is reflected in the overall length which has the most minus values for this measurement, (39.2%) for any group.

The values for facial height reflect the normal trend of mandibular dimensions showing a more or less normal distribution. An increase in minus values for maxillary height is compensated by a slight

increase in mandibular height. The angle of the mandibular plane to the cranial base reflects the slight increase in the plus values for the mandibular angle.

The incisal inclinations are characteristic of Class III showing a tendency to increased maxillary and decreased mandibular proclination and tend to compensate for the adverse jaw relationships.

Group B. "Mandibular Protrusion". (Plates 3, 5, 12, 13, 25.)

Cases in this group give the appearance of a retruded and underdeveloped middle third of the face and, although the mandible was prominent, were classed clinically as maxillary retrusion since the major fault appeared to be in the maxilla. In this group the causative factors appear to be in the cranial base, the maxilla and the mandible. In the cranial base, the major single factor is a marked tendency to a small cranial base angle with minus values 40.5%. Anterior length with 29.9% minus values is also of importance. The effects of these on maxillary-mandibular relationships have been mentioned. These values are reflected in a marked increase in the minus values for overall length, (35.8%).

The maxilla is affected in length and in height. Length PNS-ANS shows 32.9% minus values and, as is described below, the maxillary components of facial height show an increase in minus values. In the mandible the most significant factor is a marked

increase in horizontal length, plus values 37.8%. Also characteristic is a decreased mandibular angle shown by increased minus values (23.0%). The effects of these factors on overall length are opposite, with the result that it shows a normal distribution. The reasons why, in spite of a normal overall mandibular length, this group emerges from the "differential analysis" as mandibular protrusion are firstly, the decrease in the mandibular angle increases the prognathism of the mandible relative to the profile, and secondly, the effect of the reduced anterior cranial base length (S-N) on the point nasion. The more posterior this point (nasion) is relative to pogonion, the greater the angle of mandibular protrusion (\angle SNPo).

The clinical impression of maxillary underdevelopment is confirmed by the figures for facial height. Overall height shows the largest percentage of minus values for any measurement, (53.7%). Every component of facial height contributes to this decrease, mandibular height 23.9% minus values, maxillary height 43.3% and upper face height 37.3%. Maxillary height (OP¹-ANS) and upper face height (ANS-N) measure the vertical development of the maxilla. The comparison of Class III and Neutro-occlusion mean values showed a significant reduction in maxillary height (OP¹-ANS) in the mixed dentition but no significant differences were found for upper face height (ANS-N). This latter finding suggested that vertical development of

the maxilla above the floor of the nose was not abnormal in Class III. This view however does not appear to be tenable for Group B which is the only group to show increased minus and decreased plus values for this measurement. The evidence of decreased maxillary height and length suggests maxillary underdevelopment as a factor in Group B cases and whilst on the basis of the "differential analysis" Group B is correctly designated, mandibular protrusion, the clinical label of maxillary underdevelopment is also valid.

The decreased angle of the mandibular plane to the anterior cranial base with no plus values and more minus (59.5%) than 0 (40.5%) values is consequent to the increased minus values for both the cranial base and mandibular angles. The incisal angles are as in Group A characteristic of Class III with an even greater tendency to proclination of the maxillary incisors.

Group C. Maxillary Retrusion. (Plates 17,22,25.)

Clinically Group C cases present the classical picture of mandibular protrusion with a large mandibular angle, 30.5% plus values and increased facial height, the opposite of the picture in Group B. As with Group B, "the differential analysis" reversed the clinical label which for the Group C type of case was "mandibular protrusion". As in the other two groups, cranial base factors are of importance, the cranial base angle with 83.4% 0 values shows a strong

central tendency. The distribution of the individual "O" values was examined for any evidence of a tendency for the values to fall to one or other end of the $\pm 1SD$ range, but an even distribution was found.

This association of a large mandibular angle with a normal cranial base angle may explain the lack of a significant difference between the mean cranial base angles in Sanborn's samples of Class III and Normal which showed a markedly significant increase in the Class III mean mandibular angle.

In view of the relationship of the maxilla to the anterior cranial base, the finding that the minus values for the latter (25.0%) were less than in Group B (29%), was unexpected. The minus values (42.8%) for the cranial base posterior length appear to be more significant than the anterior length and indicate a more anterior position of the temporo-mandibular joint relative to the anterior cranial base and the maxilla. The maxilla is affected in antero-posterior length which shows, as might be expected, on the basis of the "differential analysis" the greatest number of minus values (35.7%) for any group. Overall maxillary height is unaffected as is shown by the components of facial height, upper face height (N-ANS) and maxillary height. (ANS-OF) The former shows a decrease in minus values, (7.2%) and the latter a normal distribution.

The mandible shows a near normal distribution for both vertical and horizontal length which suggests that

the relative protrusion of the mandible is probably due to the anterior positioning of the mandibular joint relative to the cranial base as shown by the marked increase in minus values (42.8%) for posterior cranial base length. The increase in overall mandibular length (25% plus) resulting from the increased mandibular angle, produces an increase in face height rather than protrusion, as was shown earlier. Overall facial height with increased plus and decreased minus values reflects both the increased mandibular angle with its associated increased lower face height and, as noted in discussing the maxilla, the normal vertical development of the maxilla which is in contrast with the signs of its underdevelopment in Group B.

The mandibular plane with 41.5% plus values reflects the increase in mandibular angle plus values and the maxillary plane shows the same trend to a lesser degree.

The maxillary incisal inclination in Group C differs from that in Groups A and B, Group C being the only group to show increased minus values. The reason for this can only be surmised but it may be related to a lower than normal position of the tongue which was noted in some cases in association with a markedly obtuse angle of the mandible. Any adverse effect of the maxillary incisal inclination on the reverse overjet is offset by the marked increase in minus values (47.2%) for the inclination of the lower incisors to the mandibular plane.

Summary and Conclusions."Differential Analysis."

The "differential analysis" of the Class III cases on the basis of the relative degrees of maxillary and mandibular prognathism has shown the existence of three principal groups which have been called Groups A, B and C. They correspond with three clinically recognisable cranio-facial patterns. Group A (Mx and $Mn \pm 1SD$) corresponds in general characteristics with the clinical type called "dominant mandible", but Group B ($Mx \pm 1SD$ $Mn > + 1SD$) "Mandibular protrusion" had the characteristics of the clinical type called maxillary retrusion, whilst Group C ($Mx < -1SD$ $Mn \pm 1SD$) "Maxillary retrusion" had the characteristics of the clinical type called mandibular protrusion.

The principal factor associated with mesio-occlusion on the basis of this analysis is a trend to reduced angular and linear dimensions of the cranial base which was a constant factor in all three groups except for the cranial base angle (Saddle Angle) in Group C. These variations in dimension secondarily affected maxillo-mandibular relationships. The other constant factor is a trend to reduced maxillary length in all groups. The overall height of the maxilla ($ANS-OP'+ANS-N$) behaves differently in Groups B and C. It is markedly reduced in Group B where it is associated with a reduced face height, while in Group C

it shows a tendency to increase and is associated with increased face height.

Mandibular dimensions were not so prominent a factor as might have been expected, being of most importance in Group B where a decreased angle and increased horizontal length were key factors.

In Group A mandibular dimensions were more or less average with a suggestion of dominance shown by a less than average number of minus values rather than by increased plus values, whilst in Group C the main features were the increased mandibular angle and the consequent increases in overall length and in face height.

It has been suggested earlier (Page 85) that the different facial heights seen in the female mixed and permanent Class III groups were due to the predominance in these groups of different Class III patterns.

The percentages of Groups A, B and C in the two Class III female dentitional groups are reproduced from table 21 for convenience and are as follows:-

	<u>Group A</u>	<u>Group B.</u>	<u>Group C.</u>
Mixed Dentition	49.3	43.3	5.9 %
Permanent Dent.	49.1	21.8	29.1 %

The percentage in Group A is similar in both dentitional groups; Group B, (43.3%) predominates over Group C, (5.9%) in the mixed dentition group, whilst in the permanent dentition there is a larger

percentage of Group C, (29.1%) with Group B, (21.8%). It has been shown that a reduced facial height is characteristic of Group B and an increased height of Group C. This would appear to be the explanation of the differences seen with regard to facial height in the Class III female mixed and permanent dentition groups. A similar trend, though not so marked, is seen in the male mixed and permanent Class III groups with Group B, 22.9% in the mixed and 33.3% in the permanent, compared with Group C, 11.4% in the mixed and 38.1% in the permanent.

The contrast between the facial forms in Group B and Group C (Plate 25) is marked. It raises the question - is the reduced overall maxillary height in Groups B a compensatory variation induced by the reduced mandibular angle and the resultant reduction in vertical space between the horizontal ramus and cranial base or not? - If not, does the reduced mandibular angle follow a reduction in maxillary height? Similarly, is the increased mandibular angle in Group C, with resultant reduced mandibular prognathism, induced by the lack of antero-posterior growth of the maxilla, or are the roles reversed? An examination of the full face and profile photographs of the two typical Group B and C subjects in Plate 25 shows that when the third dimension of breadth is considered the doliocephalic Group C face is elongated and compressed laterally whilst the

brachycephalic Group B face is foreshortened and broadened and it is obvious that the variations in maxillary and mandibular dimensions found in these faces are but one aspect of the larger problem of general cranio-facial morphology.

In the absence of information as to the correlation and control of the genetic influences determining cranial base, maxillary and mandibular form and size and the interaction of the environment with them, it is not possible to do other than speculate about the relative importance of the factors determining the form size and relationships of the cranio-facial structures. However in view of the evidence pointing to the cranial base as playing a leading role in determining maxillary-mandibular relationships, it is suggested that enquiry into the aetiology of antero-posterior jaw malrelationships should be directed to a study of the embryology and development of the sphenoid and the related bones which form the cranial base to determine their relationship to and effects upon the maxilla, the mandible and the temporo-mandibular articulation.

In the section that follows an analysis is made of the variations in structural dimensions and relationships in individual cases.

Mandible: \angle ArGoGn (A3), Ar-Go (L4), Go-Gn (L5)
 Ar-Gn (L6), \angle SNB (A5) \angle SNId (A7),
 \angle SNPo (A8).

The Y Axis (A15) and the angles of inclination of the upper (A12) and lower incisors (A13) were also included. The measurements were examined in each case and given a score of +1, +2, +3 or 0, depending on whether they fell within +1, +2 or +3 of the standard deviation of the corresponding Neutro-occlusion measurement, or corresponded with the mean figure. The plus or minus signs were given not according as to whether the measurement was greater or less than the standard deviation, but according to whether an increase or decrease on the mean figure was considered productive of or associated with mesio-occlusion or the reverse. The Class III factors were given a minus and the "anti" Class III a plus sign. Thus for example, all cranial base, maxillary, Y Axis and upper incisor values less than the corresponding Neutro-occlusion mean carried a minus sign and all values greater than the mean values, a plus sign. A measurement coinciding with the mean scored 0. All mandibular values greater than the mean carried a minus sign, maxillary prognathism values less than the mean and mandibular prognathism values greater than the mean carried a minus sign and vice-versa for plus signs. The nett score for a case is the sum of the plus and minus scores for each measurement and

will carry a + or - sign according to which was the more numerous.

Material.

The first dozen Class III male mixed dentition cases falling in Group A and six cases each in Groups B and C were compared with the first ten cases recorded in the male mixed dentition Neutro-occlusion group. An additional case (No.43) was also added to the Group A cases for a reason to be given. The results are shown in tables 23-25. An examination of the results in Group A (Table 24) shows in more detail the same apparent lack of individual pattern seen in the simpler analysis into 0 + and -, based on $\pm 1SD$. An attempt to find some significance in the overall scores of Class III Group A cases compared with cases in the Neutro-occlusion sample fails. Nett scores for the two groups show a similar range, only one Neutro-occlusion case (No.7) has a nett plus score. A separate examination of the scores for measurements of cranial base, maxilla and mandible in Groups A, B, C, and Neutro-occlusion again shows a wide range of individual variation, nett plus scores are found in the Class III groups, e.g. cranial base nett scores of +5, Case 20 Group A, +2, Case 16 Group B and +5, Case 60 Group C, whilst Case 8 Neutro-occlusion, has a nett cranial base score of -5.

Six cases each in Groups A, B and C and 6 Neutro-occlusion cases are shown graphically in the form of

Standard Deviation Diagrams after Hellman (1927), Figs. 21-24. These diagrams as presented, differ from the usual form in that firstly the + and - signs refer to the plus and minus scores so that the left hand side of the diagram represents the trend to Class III and the right hand side the opposite. Secondly the actual measurements are not indicated, only the fact that the measurement in question lies within +1, +2 or +3 S.D. of the mean. (Diagrams indicating the individual measurements were prepared but they did not further clarify the picture.)

A study of the four sets of diagrams brings out more clearly than the figures certain effects. Group A (Fig. 22) and Neutro-occlusion (Fig. 21) both show the various values arranged around the means with no one set of measurements, consistently going to right or left in contrast with Groups B and C, (Figs. 23, 24.) In Group B the Y Axis and mandibular prognathism and in Group C the maxillary section are consistently placed to the left of the mean. In Group C, maxillary prognathism and in Group B, mandibular prognathism behave as expected on the basis of the classification. These few cases suggest that a reduction in length of the maxilla rather than its distal position is the prime factor in maxillary retrusion. Mandibular dimensions in Group B are variable. In Case 9 protrusion is found with normal linear dimensions combined with a larger than normal angle. The reverse combination is seen in Case 14.

The clinical history of the Class III cases in Groups A, B and C shows that the majority of them have been successfully treated and the results are stable at the moment of writing. Cases 11, 21 and 43 in Group A, Cases 29, 33 in Group B and 60 in Group C, show varying degrees of relapse. There is nothing about their patterns to suggest this. It is of especial interest to find marked relapses in Group A where the basal bone malrelationship is only slight, as in Case 11 where $\angle SNA - \angle SNB = 0^\circ$. If however Case 11 were to be classed on the present jaw relationships it would fall into one of the minority groups, the maxillary prognathism being now more minus than -1SD and the mandibular prognathism more than +1SD of Neutro-occlusion. These cases are considered in more detail in Part II but are mentioned now to show that the present analysis does not offer any guide to future growth and development.

Summary and Conclusions.

The scoring system does not differentiate between Class III cases and Neutro-occlusion and does not indicate, except in a general way, the variations of parts and relationships of significance in the production of mesio-occlusion and it is not any guide to future growth. The scoring system does show, particularly in the form of the standard deviation score diagrams, the infinite variety of combinations of parts and proportions that can produce mesio-

-occlusion or Neutro-occlusion and suggests that cranio-facial analysis in terms of mean dimensions has considerable limitations when applied to individuals who differ significantly in occlusion from the normal but who do not differ markedly from the normal as regards general cranio-facial morphology. The statistical analysis, whilst giving some information as to the significance in relation to the facial pattern of the variations in size and relationship of the parts examined, does not indicate the effects of the interplay between them. Thus for example, it is not known to what extent an increased anterior cranial base length offsets a decreased cranial base angle.

In many cases it is the integration of the variables that determines balance or imbalance of the facial structures. There appears to be a trend to normal which operates by means of compensatory variation. A high value for one part being compensated by reduced values for one or more of the others. Compensatory variation is seen for instance in the association of an obtuse angled mandible with a short maxilla (antero-posteriorly) or of a small angled mandible with decreased maxillary height. This variation of parts combining to produce a similar overall effect is seen in other parts of the body. The standing height of two people may be the same but the sitting height may be markedly different, indicating variations in the other components of standing height.

Comparison of the mean values of the linear and angular measurements in the Class III and Neutro-occlusion dentitional groups for growth and developmental changes and sex differences.

A study of the mean measurements of their cranio-facial patterns has shown some significant differences between the Class III and Neutro-occlusion facial patterns and it has also been shown that the Class III cranio-facial pattern can be further differentiated into three main types with differing characteristics. The remaining sections of Part I are concerned with the second and third questions posed in the introduction, which were, whether the growth changes in the Class III pattern differed from those that occurred in Neutro-occlusion and whether the mean measurements showed any differences between the sexes.

V. Comparison of mean measurements for growth changes.

(In the following comparisons of means, reference is made to the appropriate tables of mean measurements (Tables 4-19). It is pointed out however that the "t" values given in these tables refer to differences between the Class III and the corresponding Neutro-occlusion sex and dentitional group. These are not to be confused with the "t" values in the following text which refer to differences between either the Class III or the Neutro-occlusion dentitional stages.)

Linear Dimensions.

During growth and development linear dimensions naturally increase and it is the relative amount of increase of one part compared with another and the effects such variations may have on antero-posterior relationships that are of interest to this study.

Cranial Base (Table 4).

The question of the growth of the anterior cranial base is discussed in Part II (Page 167) where it is shown that increases in length from the age of approximately seven occur mainly between foramen caecum and nasion anterior to the cranial base proper and so do not affect the antero-posterior position of the maxilla. The increments of posterior cranial base length do not differ significantly between Class III and Neutro-occlusion.

Maxilla and Mandible. (Tables 5 and 6).

The relative amounts of maxillary and mandibular increments have already been discussed (Page 80) and a decrease in maxillary length PNS-ANS as a percentage of overall mandibular length Ar-Gn, has been shown in both Class III and Neutro-occlusion, (Table 7). The decrease is more marked in Class III indicating a greater relative growth of the mandible to the maxilla than in Neutro-occlusion. Evidence supporting this will be shown in Part II in the study of the causes of relapses in corrected mesio-occlusion.

The vertical height of the mandible grows

relatively more than the horizontal length forming 58.5% of horizontal length in the deciduous, 60% in the mixed and 62% in the permanent dentition in the female Class III. The male Class III groups show similar changes from 58.2% in the deciduous to 64.3% in the permanent dentition. The Neutro-occlusion also shows similar changes from 59.2% in the deciduous to 65.4% in the permanent dentition in the female and there does not appear to be any difference in the mean growth pattern of the mandible between Neutro-occlusion and Class III.

Angular Dimensions.

Cranial Base Angle (Table 4).

Allowing for the small size of the deciduous dentition samples the cranial base angle does not alter significantly in either Class III or Neutro-occlusion.

Serial studies in Part II will show that in the deciduous dentition cases no significant changes were seen in the cranial base angle when basion was used as the posterior end of the cranial base. In the mixed and permanent dentition serial studies, changes of $\pm 2^{\circ}$ were seen in individual cases using articulare (Ar) as the posterior end point. The significance of the stability of the cranial base angle post-natally has been discussed earlier.

Mandibular Angle. (Table 6).

The male groups show no significant differences from one another. In the Class III females a significant difference is present between the mixed (130.14°) and permanent dentitions (127.4°) ($t = 2.5$)

and a similar significant difference is present between the Neutro-occlusion female mixed and permanent groups.

Discussion.

The mandibular angle shows a similar behaviour in both Class III and Neutro-occlusion. Keen (1945), Coben (1955) and Jensen and Palling (1954), report a decrease in the angle from birth onwards with the greatest change in the earlier years. Keen and also Jensen and Palling disagree with the traditional description of an increased angle in old age, Keen finding a significant increase only in the presence of loss of teeth and altered muscular stresses. Evidence from the serial studies in Part II shows a consistent tendency to decrease in the deciduous dentition cases¹ covering the ages of 5-10 years approximately. The mixed and permanent dentition cases showed a more variable picture with individual changes of from -6.5° to $+3.5^{\circ}$ which is in line with Coben's findings of individual changes in girls and boys between 8-16 years of -10° to $+3^{\circ}$ but with a mean decrease overall. On the other hand a comparison of Bjork's mean figures for 12 year old boys and conscripts shows no significant difference. (Bjork 1947). This agrees with the male mixed and permanent Class III and Neutro-occlusion groups although the latter is too deficient in older patients

¹ cases where treatment was started in the deciduous dentition.

in the permanent dentition to make it comparable on an age basis with the mixed dentition. These findings, whilst not strictly relevant to the main study, are of interest and suggest the need for further study of this aspect of mandibular growth.

Angulation of Planes to the Cranial Base. Table 15.

Maxillary Plane.

No significant differences were found between the Neutro-occlusion groups or between the mixed and permanent Class III groups. Significant differences were found between the deciduous and mixed Class III groups ($t=2.2$ female and 3.06 male.) These may be due either to the small size of the deciduous samples or to growth changes in the anterior cranial base and in the maxilla.

Mandibular Plane. No significant differences were observed between any of the groups.

Occlusal Plane.

Significant differences between the deciduous and permanent dentition reflect the occlusal changes over this period and are to be expected. No significant differences were observed between the mixed and permanent dentition groups.

Angles of Prognathism:

Maxillary Prognathism. Table 10.

Basal Prognathism /SNA. There is a slight but constant trend to decrease in Class III compared with the Neutro-occlusion which shows a slight decrease in the mixed compared with the deciduous and permanent dentition.

Alveolar Prognathism (\angle SNPr).

There is no significant difference and no trend between the Class III groups. In the Neutro-occlusion groups this angle shows a tendency to increase with age.

Mandibular Prognathism. Table 11.

Basal alveolar (\angle SNB) and alveolar prognathism (\angle SNId) show no significant differences and no trends except the female Neutro-occlusion which shows significant increases in both angles between the mixed and permanent dentitions, ($t = 2.4$ and 2.2). Class III basal mandibular prognathism (\angle SNPo) shows a tendency to increase in both sexes which is not however significant. The female Neutro-occlusion shows a significant difference between the mixed and permanent dentitions, ($t = 2.9$).

(In assessing these findings in the discussion, the greater incidence of Group B ($Mx+1SD$ Mn) $\rangle +1SD$, i.e. - \angle SNPo $\rangle + 1SD$.) in the mixed dentition and its smaller incidence in the permanent dentition with consequent effects on the means for mandibular prognathism is taken into account. The same factor affects the changes in the Y Axis.)

The Angle of Convexity (\angle NAPo) Table 13.

The angle of convexity shows increases in a negative direction between all groups with significant differences between both the female ($t = 3.1$) and male ($t = 3.5$) deciduous and mixed dentitions. The

Neutro-occlusion groups do not show any marked changes between the mixed and permanent groups.

The Y Axis. (/NSGn) Table 16.

The Y Axis shows a significant increase in the female ($t = 2.06$) and nearly so in the male ($t = 1.9$) between the Class III mixed and permanent dentitions. There are no significant changes in the Neutro-occlusion groups.

Chin Angle. (/Ii-Po/Go-Gn) Table 17.

There is a general trend towards a decrease in the chin angle from the deciduous to the permanent dentition with significant differences between all the female groups, (deciduous/mixed $t = 4.09$, mixed/permanent $t = 4.4$.) The Neutro-occlusion follows a similar pattern between the deciduous and mixed dentitions but there is no marked difference between the mixed and permanent dentition groups in contrast with the Class III groups.

Incisal Inclination.

There is a common trend in both sexes to increased proclination of the upper incisors and retroclination of the lower incisors from the deciduous to the permanent dentition. By contrast in the Neutro-occlusion both the upper and lower incisors show a tendency to increased proclination.

Overjet and Overbite.

The overbite tends to decrease between the mixed and permanent dentitions in Class III. This

is more accurately reflected in the female groups because of the more satisfactory samples as regards age distribution and numbers compared with the male groups, which however show a similar trend. The reverse overjet shows a decrease in the female between the mixed and permanent dentitions. There is little difference in the male groups. Neutro-occlusion shows no marked change between the mixed and permanent dentitions.

Discussion.

The general picture in both Class III and Neutro-occlusion is of a stability of the overall pattern between the different ages. There is no marked change in the angular relationships of the component parts to the cranial base and this itself shows little change in the angle between its anterior and posterior sections.

Despite this overall stability there is a trend in Class III toward a change in the profile which becomes more concave with an increase in mandibular basal prognathism while maxillary basal prognathism tends to decrease. This change in relative basal mandibular prognathism is reflected in the increased angle of convexity, in the decrease in chin angle and the increased proclination of the upper and retro-clination of the lower incisors.

It agrees with the observations made in the serial studies in Part II of treated cases which

changed their Groups (differential analysis Groups A, B and C) due to alterations in the values of maxillary and mandibular basal prognathism. This contrasts with the Neutro-occlusion groups where both maxillary and mandibular basal prognathism tend to increase (the latter more markedly) in the permanent dentition compared with the mixed dentition. The latter finding agrees with those of Bjork (1947) and Lande (1952).

These findings suggest that the comparative failure of the maxilla in Class III to move forward with nasion and pogonion (as is evidenced by the negative increase in the angle of convexity \angle NAPo) is due more to a lack of maxillary forward growth than to an excess of mandibular forward growth. This may be the explanation of the relapsing or worsening of mesio-occlusion cases between the mixed and permanent dentitions. Evidence supporting this is seen in the greater incidence of "maxillary retrusion" cases (Group C) in the permanent dentition, (described in the previous section) compared with the mixed dentition and in the evidence from the serial studies in Part II of feebleness of maxillary growth in some cases which relapsed in the permanent dentition. There is also evidence from the serial studies that in some cases the increased basal mandibular prognathism (\angle SNPo) may be due to localised accretion of bone at the symphysis rather than to a more anterior position

of the mandible as a whole.

In conclusion the Class III pattern does not differ from Neutro-occlusion in the general progress of growth and development. The basic malrelationships as determined by the cranial base factors persist but Class III differs from Neutro-occlusion in showing a tendency to decreased maxillary forward growth which causes the malrelationship to worsen between the mixed and permanent dentitions. Evidence in support of this will be adduced from the serial studies in Part II. It must be stressed that many Class III occlusions do not worsen materially over the years and that the effect on the mean figures for measurements at different ages, of those that do, may be only to indicate a tendency rather than cause a statistically significant difference.

VI. Comparison of the male and female Class III mean measurements for sex differences.

This is the last of the questions asked in the introduction to be considered in this part of the study. Apart from the work of Coben (1955), no reference could be found in general roentgenographic cephalometric studies to comparisons of the sexes. None of the Class III studies mentioned in the review of the literature dealt with this aspect and it was considered to be of general interest to do so. In addition it was desired to test a clinical impression that the Group B type of Class III was more common in girls.

Method.

The material has been examined for sex differences between the male and female Class III groups by a comparison of the means of the linear and angular measurements for the sexes. The incidence of the various types of Class III malocclusion as defined by the differential analysis has also been examined for sex differences.

Results.

The differences are almost entirely confined to the linear dimensions which are significantly larger in the male mixed and permanent dentition groups for all the dimensions examined. These were the linear dimensions of the cranial base, the maxilla, the mandible and all the components of facial height.

On the other hand the means of the angular dimensions show no significant differences. The angles examined were the cranial base angle, the mandibular angle, the angles of prognathism, the Y Axis, the incisal angulations and the angles of the maxillary and mandibular planes to the cranial base.

From this it is concluded that the mean Class III pattern is the same in both sexes, the differences being solely one of size.

Particular attention was given to the mandibular angle for which a sex difference is claimed by some, the female angle being said to be more obtuse, e.g., Herdlicka (1920), (1940), and Izard (1927). At first examination a sex difference appeared probable between the male and female permanent dentition, the female angle being the larger but the difference was not statistically significant ($t = 1.9$). This agrees with Keen, (1950), Werner (1955) and Jensen and Palling (1954), who, while all agreeing that the female angle tended to be the larger, did not find the differences significant statistically. It is of interest to note that the minimum value for the mandibular angle found in this study was a 116° in a female subject and the maximum of 144.5° was in a male. This indicates the dangers of applying mean findings to individual cases.

The examination of the percentages of males and females in the Class III groups A, B and C as established by the differential analysis shows that if

the sexes are compared without regard to the dentitional groups there is no marked difference between the sexes as the following figures show:-

Table 26. % Males and Females in Groups A, B, C.

	<u>Group A.</u>		<u>Group B.</u>		<u>Group C.</u>	
	F	M	F	M	F	M
%	49.2	49.4	35.4	32.2	15.4	18.4
No. of cases	64	43	46	28	20	16
100% Female.	(F) = 130.		100% Male (M) = 87.			

An examination of the percentages of males and females in Groups A, B, C in the dentitional groups (Table 21, Appndx.) shows a somewhat different picture to that in Table 26.¹ In the mixed dentition Group A shows an approximately similar distribution in both sexes, 49.3% female and 54.1% male, compared with Group B, 43% female and 22.9% male. Group C, with a smaller number of both sexes, shows 5.9% female and 11.4% male. The greater percentage of females than males in Group B confirms the impression formed clinically that more girls than boys had presented with this Class III type in this study.

In the permanent dentition useful comparisons are difficult because of the relatively small number of males. In group A the females show the same figure, 49%, as in the mixed dentition, Group B shows approximately half as many, 21% and Group C more than twice as many, 29%, as in the mixed dentition. The males show a marked reduction in Group A to 23% with

¹ Tables 26-38 will be found accompanying the text.

increases in Group B 33% and Group C 30%. It must be stressed with regard to these figures that the sample is comprised of patients who sought advice or treatment and does not necessarily represent a true picture of the sex incidence in the population at large, particularly in respect of the young adult patients who came mainly on their own initiative. In this latter group therefore, girls being more conscious of their appearance, could be expected to predominate, not only in total numbers but also in the less severe conditions represented by Group A.

In view of all these factors it is not considered that the evidence shows any sex difference in the incidence of the various patterns of Class III malocclusion. The most that can be said is that there is the hint of a trend to the more frequent occurrence of mandibular protrusion (Group B) in females and of maxillary retrusion (Group C) in males. In so far as this observation is valid it is of interest in relation to the opposite condition of disto-occlusion where both Young et al. (1932) and Elasser and Wylie (1948) found maxillary protrusion more frequently in males and mandibular retrusion more frequently in females.

Summary Part I.Material and Methods.

Using a standardised technique, a roentgenographic cephalometric analysis has been made of 226 patients diagnosed as having Angle's Class III malocclusion and of 157 patients with Neutro-occlusion (either a normal occlusion or an Angle's Class I malocclusion.) The Class III and Neutro-occlusion samples were divided into groups based on the sex and the stage of occlusal development as follows:-

1. Male and female deciduous dentition.
2. Male and female mixed dentition.
3. Male and female permanent dentition.

The purpose of the analysis of the Class III and Neutro-occlusion samples was to determine:-

1. Is there a specific cranio-facial pattern associated with mesio-occlusion? If not, are there various relationships and proportions of the structures involved that can combine to produce a similar occlusal picture? If this is so how do these proportions and relationships differ from those associated with neutro-occlusion?
2. Do the growth changes in cranio-facial pattern differ in mesio-occlusion from those that occur in neutro-occlusion?
3. Is there any evidence of sex differences in the cranio-facial pattern in mesio-occlusion?

The means by which these problems were investigated were as follows:-

Facial diagrams for each sex and dentitional Class III and Neutro-occlusion group were constructed from the mean values for each group of the linear and angular measurements made of the cranio-facial structures and relationships in the cephalometric analysis. The facial diagrams so constructed were superimposed, the Class III upon the corresponding Neutro-occlusion diagram and the differences between these observed.

The mean measurements of the component structures in the Class III facial diagrams were compared with those of the Neutro-occlusion for differences of statistical significance, a "t" value of 2.0 being regarded as significant.

A differential analysis of the Class III cases was made based on the degree of maxillary and mandibular prognathism in each case using as a measure of normal $\pm 1SD$ of maxillary and mandibular prognathism in the corresponding Neutro-occlusion dentitional sex group.

The Class III cases in the three main groups A, B and C, resulting from this analysis were then examined individually in respect of certain linear and angular measurements. A "0", "+" or "-" was recorded for each measurement in each case depending on whether it was within, more than or less than $\pm 1SD$

of the Neutro-occlusion measurement for the corresponding Sex/Dentitional group. The totals of "0", "+" and "-" for each measurement in Groups A, B and C were then expressed as percentages of the combined "0" "+" and "-" total and the results in the three groups compared.

An individual analysis of ten randomly chosen mixed dentition Neutro-occlusion cases and of a number of mixed dentition Class III cases in each of the Groups A (13) B (6) and C (6), was done giving each case a score based on ± 3 , ± 2 or $\pm 1SD$. The results were examined for evidence of score differences between the Neutro-occlusion and Group A, B and C cases. Standard Deviation diagrams were made of six cases each of Groups A, B and C and compared with the diagrams for six of the Neutro-occlusion cases.

An examination was made of the differences between the means of the dentitional groups, both Class III and Neutro-occlusion, for evidence of growth changes between the different stages of occlusal development.

Finally the Class III mean values were tested for sex differences as was also the incidence of the different Class III cranio-facial patterns resulting from the differential analysis.

Findings and Conclusions.

The principal findings of the investigations carried out and the conclusions based on them are as follows:-

1. The mean cranio-facial pattern in Class III malocclusions (mesio-occlusion) differs from that in Neutro-occlusion and is a composite picture made up of differing Class III cranio-facial patterns.

2. The Class III profile is concave with a negative angle of convexity (Downs). Maxillary prognathism is decreased and that of the mandible increased, the latter being of statistical significance more frequently than the former. Facial height varies according to the Class III type and may be within the normal range increased or decreased. The upper incisors are proclinated and the lower incisors retroclinated and there is typically a reverse overjet and overbite.

3. The Class III profile is the resultant of significant variations in the dimensions and relationships of the cranial base, the maxilla and the mandible.

4. The variations that may be present in these structures are:-

i. Cranial Base: The dimensions of the cranial base (saddle) angle, anterior length, posterior length and overall length, all show significant decreases. These are the most consistent factors in all the Class III samples and this consistency indicates that the cranial base is a primary factor in Class III morphology.

ii. The maxilla shows a significant reduction in antero-posterior length in the larger samples and less frequently a significant reduction in vertical dimension.

iii. The mandible shows trends to increased vertical height, horizontal and overall lengths, that are not significant except in the older age groups. The mandibular angle tends to be larger but the difference is not significant.

5. Distinctive Class III cranio-facial patterns are produced by differing combinations of cranial base, maxillary and mandibular dimensional variations. There are three principal Class III cranio-facial types which have been called:-

- i. "Dominant Mandible" (Group A differential analysis)
- ii. "Mandibular Protrusion" (Group B)
- iii. "Maxillary Retrusion" (Group C)

6. The characteristic features of these three groups are as follows:-

i. Dominant Mandible (Group A.)

A tendency to decrease in the cranial base angle and all cranial base linear dimensions. Maxillary length tends to be less whilst mandibular dimensions are normal. The cause of the relative mandibular protrusion lying in the cranial base and maxilla. This type in general resembles Neutro-occlusion apart from the dominant appearance of the mandible.

ii. Mandibular Protrusion (Group B.).

A marked tendency to a small cranial base angle and a lesser tendency to a reduction in anterior cranial base length. Maxillary length and height are reduced. The mandible is characterised by a normal or decreased mandibular angle and a marked increase in horizontal length. Facial height is reduced.

iii. Maxillary Retrusion (Group C).

The accepted picture of a Class III malocclusion. The cranial base angle has a strong normal tendency but cranial base posterior length is markedly less. The maxillary length is less. The mandibular angle is more obtuse increasing the overall length but the vertical and horizontal components tend to be normal. Facial height is markedly increased.

7. The analysis of the measurements of individual Class III and Neutro - occlusion cases by standard deviation scores failed to establish any pattern of correlation between one variant and another except for a general appearance of compensatory variation whereby extreme variations in one part appeared to be compensated by an opposite variation in an associated structure.

8. The study of growth changes by a comparison of the mean linear and angular dimensions of the three dentitional stages showed that the growth pattern in Class III like that in Neutro-occlusion displays a general stability. The cranial base angle shows no

significant change and there are no marked changes in the angular relationships of the other structures to the cranial base.

Class III differs from Neutro-occlusion in one important respect. The normal trend to a greater relative increase in mandibular basal prognathism than maxillary basal prognathism between the mixed and permanent dentition is exaggerated in Class III by a tendency for maxillary prognathism to decrease. This is reflected in a decrease in maxillary length as a percentage of mandibular length, an increase in the negative degree of the angle of convexity and in the increased proclination of the upper and retroclination of the lower incisors. In contrast Neutro-occlusion shows no marked changes in the angle of convexity and a tendency to increased proclination of both upper and lower incisors.

9. No sex differences apart from that of size were found in Class III. There was a tendency for the mandibular angle to be larger in females but this was not significant and the smallest mandibular angle recorded was for a female. There was a suggestion of a greater incidence of mandibular protrusion (Group B) in females and of maxillary retrusion (Group C) in males.

Final Conclusions Part I.

1. The cranio-facial pattern in Class III differs from that of Neutro-occlusion. The differences arise from variations which, in order of significance, are found in the cranial base, the maxilla and the mandible.

2. Different combinations of these variations produce three main Class III cranio-facial patterns here called, "Dominant Mandible", "Mandibular Protrusion", and "Maxillary Retrusion."

3. The cranial base variations are a reduction in the angle and in the linear dimensions which separately and collectively give rise to a more forward position of the mandible relative to the maxilla.

4. The maxilla tends to be deficient in length and sometimes in height.

5. The linear dimensions of the mandible are not necessarily greater than normal tending to become relatively greater with age. Contrary to previous findings an increased mandibular angle is not an essential factor in the Class III picture. The angle may be of less than average size. It is stressed that an increase in the mandibular angle per se is not a cause of mandibular protrusion and has the opposite effect, it is a decrease in the angle that increases the degree of prognathism.

6. The cranial base is the most consistent

variant in all types of Class III malocclusions and it is suggested that, through its relationships to the maxilla and the temporo-mandibular joint, it is the primary factor in determining maxillary-mandibular relationships. The post-natal stability of the cranial base angle suggests that the genesis of a Class III malocclusion takes place early in life and probably before birth. The possibility of future amelioration or deterioration in jaw relationships depending on the relative forward growth of maxilla to mandible. There is a tendency in Class III for this ratio to be unfavourable.

Part II.Roentgenographic Cephalometric Analysis of
Treated Cases of Mesio-occlusion.Introduction:

Part II is concerned with the last two questions posed in the introduction. They are:-

4. What are the changes that follow Orthodontic treatment and to what extent are these changes the result of treatment or of growth?
5. What are the factors associated with the relapse of a corrected mesio-occlusion?

The changes following treatment and the causes of relapse were determined by a cephalometric analysis of lateral skull radiographs taken before, during and after treatment. Clinical observations were used where possible to support and clarify the results of the cephalometric analysis.

Correlation with the conclusions of the first part of this study is made where relevant, for example in the study of the growth changes in the treated cases.

Review of Literature.

The Roentgenographic cephalometric analysis of changes following treatment in Class III cases has received little attention. Brodie, Downs and Goldstein (1938) included a few cases of Class III

in their paper concerned with all classes of malocclusion. They stated in the summary of their observations on the changes they found in Class III cases, "Because of the smallness of the sample, no definite conclusions may be drawn except that treatment seemed to have little or no effect on any structure other than the alveolar process."

Apart from some illustrative cases in a paper by McCallin (1955) on the diagnosis and treatment of mesio-occlusion and references to individual Class III cases in growth studies such as those of Bjork (1951) and Donovan (1953), no further review of treatment or growth changes in a series of Class III cases appeared until the paper of Braccisi and Lucchese (1958) on the skeletal and dental changes in 30 treated cases of Class III malocclusion aged 8-12 years. Their conclusions may be summarised by saying that they found successful treatment depended on a favourable pattern of growth. They found in some cases an increase in basal maxillary mandibular disproportion greater than the increase in normal subjects over the same period and this "adverse bony base ratio is not modified by treatment."

Gugny (1959) reported on changes in two cases and stressed the dominance of growth rather than the effects of appliance therapy in determining the results of treatment. Parker (1960) and Gould (1960) have each described changes in a single case.

Material.

The material consisted of serial roentgenographic cephalometric records, dental record casts and full face and profile photographs of 139 cases of mesio-occlusion. Nine cases judged untreatable by Orthodontic means were referred for surgical correction, e.g. - Case PM14 Plate 25. The remainder were divided into groups based on the stage of the dentition at the first examination and comprised:-

Deciduous Dentition	14
Mixed Dentition	96
Permanent Dentition	20
Total	<u>130</u>

Methods of Treatment.

In the majority of cases appliance treatment was used with the primary aim of correcting the incisal relationship but in a few cases observation only was thought necessary. The method of treatment was mainly by removable appliances, other forms of treatment included functional appliances, occipital traction by means of a chin cap, and head gear and intermaxillary traction by fixed appliances. For convenience abbreviations are used in the text to designate the type of appliance used in a particular case and a glossary of the abbreviations used is given below:-

A/P Ex Antero-posterior Expansion using a Johnson Twin Wire Arch with coil springs on the buccal tubes.

C.L.I.P.	Cast Lower Inclined Plane cemented on to the lower incisors and canines.
Funct.	Functional Appliance. Reverse Andresen or Bimler type appliances.
L.R.A.	Lower Removable Appliance to retract the lower incisors with molar capping to open the bite.
O.M.T.	Occipito-mental Traction:- Occipital traction plus forward traction on the maxilla by elastic bands attached to posts on the chin cap.
O.T.	Occipital Traction:- Backward traction on the mandible with elastic traction from a chin cap to a head cap.
R.I.M.T.	Reverse Intermaxillary Traction by means of fixed appliances.
T.W.A.	Johnson Twin Wire Arch.
U.R.A.	Upper Removable Appliances with finger springs, screws, or rubber pegs to procline the upper incisors. The bite is opened to unlock the incisor bite by molar capping.

Methods of Analysis.

A. Measurement of Angular Changes.

The technique used in the roentgenographic cephalometrics analysis was the same as that used in the analysis in Part I. The methods of transferring the cranial base reference line and the incisal axis from the original tracing to subsequent tracings of the same patient have been described.

The principal angles studied before and after treatment are given overleaf, together with the

abbreviations used to indicate them in the tables of angular changes.

<u>Angle.</u>	<u>Abbreviation.</u>
1. Angle of Upper Incisor to cranial base reference line.	UI.
2. Angle of Lower Incisor to Mandibular Plane.	LI.
3. The difference between \angle SNA and \angle SNB	A/B diff.
4. The Y Axis \angle NSGn	Y.Ax.
5. The Angle of the Occlusal Plane to the Cranial Base reference line.	O.P.
6. The Angle of the Mandibular Plane to the Cranial Base reference line.	MnP.
7. The Mandibular Angle \angle ArGOgn	Mn \angle
8. The Angle of the Maxillary Plane to the Cranial Base reference line.	MxP.
9. The Angle of Convexity.	\angle Con.

The records of angular changes in individual cases in the mixed and permanent dentitions are tabulated in the Appendix.¹ The cranial base reference line is transferred as described earlier (Page 56) because in some cases its anterior end does not pass through nasion and because it is in the same relationship in all tracings of the same individual to the anterior cranial base, it is referred to as the cranial base reference line rather than as the S-N line. As explained earlier the point of intersection of the line with the frontal or nasal bone is used as nasion for angular measurements in cases where nasion in later traces of X-rays of the same individual does not lie on the S-N line transferred from the first

tracing. Nasion is described as "constant" if it lies on the cranial base line in serial X-ray tracings.

In the deciduous dentition cases where the anterior cranial base was still growing, the maximum superimposition possible was made along the horizontal portion of De Coster's line.

B. Assessment of Changes Due to Growth.

The direction and amount of growth in each case was assessed by superimposing the successive tracings on the cranial base line to observe the general direction and amount of growth, followed by individual superimposition of the maxillary and mandibular outlines using, as described earlier, the maxillary plane with PNS registered and a plane tangent to the lower border of the mandible at the angle and passing through menton with Gn registered. It is not practicable to describe in detail the growth changes in each of the recorded cases apart from cases of special interest, and an average picture only of the material as a whole can be given. The amount and direction of change was not measured and is described in general terms.

Findings.

Introduction:

It has been shown in Part I that variations in the cranial base area are among the primary factors associated with mesio-occlusion and it is not to be expected that the application of corrective forces to the dento-alveolar structures will modify the mesio-occlusion cranio-facial pattern in this area.

Theoretically the most that can be expected is a modification of the adverse ratio of mandibular to maxillary growth sufficient to permit stable normal incisal occlusal relationships. Whether or not Orthodontic treatment is able to alter or modify the inherent pattern of jaw growth is however an extremely controversial question and the findings in this study do not support the positive view. It will be shown in the following sections that the primary effects of Orthodontic treatment are limited to the teeth and alveolar bone but secondary effects on mandibular position consequent upon the corrected incisal relationships do also occur. Further, it will be shown that the growth patterns of the maxilla and mandible are not only not altered by treatment but also that they determine the success or failure of treatment and the long term stability or relapse of the treated case.

The findings are considered under three main headings:-

- I. Treatment and growth changes in the cases whose treatment was started in the deciduous dentition.
- II. Treatment and growth changes in the cases whose treatment was started in the mixed or permanent dentition.
- III. A comparison of the treatment and growth changes in a series of relapsed cases with those in a series of successfully treated cases.

I. Deciduous Dentition.

The changes noted in the 14 deciduous dentition cases during and after treatment are considered in two main respects: (A) The effects of treatment, and (B) growth changes.

(A). Effects of Treatment.

The aspects of treatment of especial interest in the deciduous dentition cases are twofold. Firstly to see whether the correction of the deciduous incisor occlusion influenced the occlusion of the permanent incisors. Secondly, to measure if possible any effects upon the mandible of backward traction upon it. (The treatment changes in the deciduous dentition cases after the eruption of the permanent incisors presented a similar picture of course to these cases started in the mixed dentition and so are not discussed, as the same ground will be covered in more detail when describing the mixed dentition cases. Individual case histories are given in the appendix.¹)

1. Results following incisal correction in the
Deciduous Dentition.

The correction of a reverse overjet and overbite of the deciduous incisors either by appliance treatment or by grinding the occlusion had no effect on the occlusion of the permanent incisors. In the five cases so treated the permanent incisors erupted into a reverse overjet and overbite.

Discussion.

In the past it has been accepted as part of the rationale of the treatment of mesio-occlusion in the deciduous dentition that the correction of the deciduous dentition incisors would benefit the occlusion of the permanent incisors. The few cases so treated in this study do not support this assumption. However Ritchie (1960) reports that in two out of four uniovular quadruplets, correction of linguallly occluding deciduous incisors was followed by normal occlusion of the permanent incisors. In the other two the permanent incisors erupted in lingual occlusion. Except in the case of a forced or functional protrusion where, following correction, the mandible occludes in a less forward position, there is no reason why the deciduous incisor correction should affect the permanent incisor relationship.

The evidence of Breitner (1940) is that the forming crown of a permanent tooth is deflected by the tilting of a deciduous tooth root in an opposite

direction to that of the deciduous crown. Any effect on the permanent incisor that proclination of an upper deciduous incisor might have would therefore be unfavourable.

In this study an examination of the relationship of the deciduous maxillary incisor roots to the permanent incisor crowns showed that at the age at which treatment is worthwhile the permanent crown lies above the root of the deciduous incisor. At a later age the deciduous root is being resorbed and treatment is not justified in view of the approaching shedding of the deciduous incisors. Any effect on the supporting alveolar bone of the incisal proclination is temporary as this bone is of course resorbed with the shedding of the deciduous tooth, the alveolar bone of the permanent incisor grows up with the erupting tooth. This is clearly seen in some of the serial studies.

The relationships of the permanent incisors must be determined by other factors. This conclusion is supported by reports of self correction of the incisors with the change of dentition, Kantorowicz (1926) Korkhaus (1934) (1957b) and it is possible that Ritchie's two successful cases would have shown self correction without treatment. The factors that determine the permanent incisor relationship are discussed further in the section on growth and development changes.

A. Effects of Treatment contd:

2. Results of Head and Chin Cap Treatment.

This time honoured appliance, probably first used by Gunnell in 1822 (Weinberger 1926), was only employed in cases showing a marked reverse overjet. The analysis of the results obtained do not support any claims that its use will restrict mandibular growth, alter mandibular form or change the direction of mandibular growth. Three patient, DF4, DM3 and DF5 were treated for five years, four years and for seven months respectively, by this method. The increases in overall mandibular length (Ar-Gn) and the changes in the mandibular angle and the Y Axis were compared with those occurring in seven patients who were not so treated. The results are shown in Table 27 (Page 160).

Increases in mandibular length were greater in the occipital traction group than in 6 of the 7 non-traction cases. Case D.F.5 (Plate 3) showed the greatest decrease in mandibular angle -4° but she wore the appliance for only 7 months. The three traction cases showed an increase in the Y Axis, the greatest, $+3^{\circ}$, being in Case DF5, but five of the non-traction cases also showed increases of from $+0.5^{\circ}$ to $+3^{\circ}$, one showed no change and one a decrease. Clinical observation showed no improvement in the occlusion of the buccal segments in Case DF4 (Plate 2). The improvement in the occlusion in Case DM3 (plate 5) was scribed

more to the influence of a forward traction on the maxillary teeth than to backward traction on the mandible.

Table 27. Comparison of linear and angular growth changes in Traction (T) and Non-traction (NT) cases in mandibular length Ar-Gn. Mandibular Angle \angle ArGoGn, Y Axis \angle NSGn. Period under observation, P.O..

Case	P.O. Y.M.	T/NT	Ar-Gn	\angle ArGoGn	Y Axis.
DF4	5-0	T5Y	+16.1	+1.5	+2.5
DF5	4-0	T7M	+10.1	-4.0	+3.0
DM3*	4-10	T4Y	+10.1	-2.0	+1.5
DF1	3-10	NT	+9.8	-3.0	+2.0
DM2	2-8	NT	+8.1	-2.0	0.0
DM4	3-8	NT	+6.1	-2.0	-1.0
DM5	4-5	NT	+14.2	-2.0	+2.5
DM6	3-4	NT	+9.3	-1.0	+0.5
DM8	3-6	NT	+9.3	+0.5	+1.0
DM9	4-3	NT	+9.0	-1.5	+3.0

* = Occipito-mental traction from age 8-11yrs.

Discussion.

Continuous pressure can distort permanently, the shape of a growing bone as is shown by foot binding and similar practices. Intermittent pressure, as applied by the chin cap worn at night only, can produce local effects as is shown in its successful use by McCallin (1955) and others, to retrocline lower incisors. In order to produce a more general

effect, pressure must be applied to the cartilaginous part of the growing condyle and it is doubtful if any pressure from occipital traction does this. It is more than probable that the backward and upward force is countered by the mandibular musculature and ligaments. In their recent experimental work on animals, Salter and Field (1960) have shown lesions varying from superficial necrosis to the loss of the full thickness of an articular cartilage as a result of continuous compression. The mandibular cartilage could therefore be expected to show some diminished activity if it was under pressure, which would result in diminished mandibular growth.

The evidence presented here does not warrant any generalisation being concerned with only three cases but, taken in conjunction with the considerations mentioned above, it is sufficient to raise doubts as to the value of this method of treatment when used with the aim of modifying the direction or amount of mandibular growth.

B. Growth and Developmental Changes.

The aspects of growth and development of especial interest in the period covered by the deciduous dentition cases are those concerning:-

1. The factors in the development of the permanent incisor occlusion.
2. The growth of the anterior cranial base.
3. Growth changes in the mandible.

1. The development of the permanent incisor occlusion.

This is of interest because of the possibility described earlier of the permanent incisors erupting into normal occlusion following a Class III occlusion of the deciduous incisors. It was thought that one explanation of the cases of self correction quoted could be that the axial inclinations of upper and lower incisors were favourable to normal occlusion and that conversely the occurrence of a lingual occlusion of the upper incisors, as in all the cases observed in this study, could be due to unfavourable axial incisal inclinations. An examination of the material was therefore made from this viewpoint. The records of all cases were not complete and the available data regarding the pre- and post-erupted inclinations of the upper and lower incisors in 13 Class III cases is shown in Table 28, (cephalometric records were not available in one case). These figures are compared in Table 29 with the figures for the 14 Neutro-occlusion cases and with figures for 8 cases given by Tulley (1957) in a study of the path of eruption of the permanent incisor. Tulley's paper, apart from a reference by Moyers, Harvold et al. (1954) to unpublished work by Harvold, was the only one on the subject to be found. The study of Table 29 shows that the Class III cases predominate in the higher degrees of proclination for the upper incisors, Section A, and show no marked difference in

Table:28:

Axial inclination in degrees of upper and lower incisors to the anterior cranial base and Mn Plane before and after eruption.

Case No.	Upper incisor			Lower incisor			
	Before eruption	After		Before eruption	After		
DF1	106.5	95.5	99.0	72.5	73.0	91.0	
DF4		105.0	105.0	-	-	-	
DF5		111.5	104.5	-	86.5	90.0	
DF6		100.5	-	-	-	-	
DF7		102.0	111.0 ⁺	-	111.5	112.5	
DM2		94.5	89.0	-	77.5	89.0	
DM3	107.5	104.5	116.0 ⁺	-	75.0	89.5	
DM4	97	100	95	116.0 ⁺	79.0	83.0	95.0
DM5	108.0	100.0	103.0	-	85.5	88.0	
DM6		94.0	103.0 ⁺	-	-	-	
DM8		86.4	95.0	-	-	76.5	
DM9	98.5	100.5	-	-	-	-	
DM10	89.0	90.0	-	79.5	78.5	-	

+These cases were under treatment during the eruption of the incisors and some of the increased proclination is a result of treatment.

Table 29. Comparison of pre-eruptive axial inclination of upper (A) and lower (B) incisors in Class III cases with Neutro-occlusion and Tulley's cases. (C) Skeletal Classification of Class III and Neutro-occlusion cases in A.

A.	Upper incisor inclination between				
	80-90°	90-100°	100-110°	110-120°	120°+
<u>CIII</u>	2	3	6	1	-
N.	2	8	2	1	1
Tull.	1	6	2	-	-
B.	Lower incisor inclination between				
	60-70°	70-80°	80-90°	90-100°	100-110°
<u>CIII</u>	-	5	3	-	1
N.	-	3	2	3	-
Tull.	1	3	5	-	-
C.	Skeletal Classification of Class <u>III</u> and Neutro. cases in A.				
	<u>SKI</u>	<u>SKII</u>	<u>SKIII</u>		
\angle SNA- \angle SNB	+2°-+4°	+5° and above	2° and less		
<u>CIII</u>	1	1	10		
N.	6	7	1		

N = Neutro-occlusion. Tull. = Tulley's cases - Normal and Class II

Tulley used the same line S-N for measuring the upper incisor inclination as used in this study. His mandibular base line is not defined but may safely be assumed to be one of the standard constructions and as the figures are to be compared in 10° ranges any slight differences due to using a different base to the one in this study can be ignored.

the lower incisor inclination from the Neutro-occlusion and Tulley's cases (Section B.)

Section C of Table 29 shows the skeletal classification (Page 89, Part I) of the Class III and Neutro-occlusion cases. Apart from one case in Skeletal Class II Case No. DF4, (thyroid deficiency) which has an atypical skeletal pattern, and one case in Skeletal Class I, all the Class III cases are skeletal Class III, whilst only one of the Neutro-occlusion cases comes in this class. From this it appears that the antero-posterior relationship of the jaws rather than the incisal inclination is the primary factor in determining the occlusal relationships of the upper and lower incisors. This is of particular importance in relation to the material examined, as, with the exception of cases No. DF4, DF5, DM3 and DM9, the Class III cases show either an edge to edge occlusion or a slight reverse overjet of the deciduous incisors and in these cases an adverse incisal inclination can be expected to be the crucial factor in determining incisal relationships.

As regards post-eruptive inclination, compared with Tulley's series, which show a uniform trend to increased proclination in the post-eruptive phase in both upper and lower incisors, the Class III cases are variable and this is no doubt related to the adverse reciprocal pressures on the incisors.

In two cases in which the post-eruptive

inclination of the lower incisor was recorded before and after the eruption of the upper incisor, an increase in inclination was shown after the eruption of the upper incisor.

	<u>Case DM2. Case DM8.</u>	
Inclination of $\bar{1}$ before eruption	77.5°	
" " $\bar{1}$ after "	89.0	76.5
" " $\bar{1}$ " eruption of <u>1</u>	93.5	83.5°

This observation is of importance in relation to the question of the forced protrusion said to be produced by premature incisal contact with forward displacement of the mandible to avoid the incisal occlusal interference, the so called "false Class III." It would appear that in cases where the mutual adjustment of the incisors has occurred, the incisal occlusion is not the primary factor in inducing a forward placement of the mandible in occlusion.

After the correction of the incisor relationship in case DM8, the lower incisor inclination fell back to 78° without treatment. This spontaneous retroclination of the lower incisor will be shown to be common following correction of the reverse incisal occlusion in the mixed dentition cases and is discussed further in that section.

In conclusion, the evidence shows that a favourable or an unfavourable incisal inclination is not the primary factor in determining the incisal relation-

-ships of the permanent incisors. The determining factor is the basal bone relationship and this being so, it suggests that the cause of the self correction seen in some Class III cases must be sought in an improvement in basal bone relationships because of growth coincident with the eruption of the permanent incisors.

2. Growth changes in the Cranial Base in the deciduous dentition cases.

In Part I the cranial base emerged from the comparison of mean measurements and the differential analysis as an important factor in the Class III cranio-facial pattern. Any information as to its behaviour in growth is therefore of considerable interest. In addition, as described earlier, the use of De Coster's line for the superimposition of serial tracings, is based on the findings of the relative stability of the anterior cranial base after 7 - 8 years of age. As is shown in Plate (26), the use of De Coster's line, rather than the sella-nasion line, makes a vital difference to the interpretation of the serial tracings. Evidence supporting the choice of this line in preference to sella-nasion is therefore of importance.

Findings.

Cessation of growth in the Anterior Cranial Base (Fig.25)

It is of course not possible to determine exactly when growth ceases from the relatively infrequent

serial tracings. But if growth has ceased, then the ages at which it has done so must be somewhere between the age of the tracing in which the anterior cranial base shows no change when compared with later tracings, and the age of the tracing preceeding it. Tabulating these two dates for the cases examined gives the following picture referring to the earlier age as "A" and the later age as "B".

Table 30.

Age B = Age of tracing after which succeeding traces showed no change in De Coster's line.

Age A = Age of tracing preceeding tracing in column B.

<u>Case No.</u>	<u>A</u>		<u>B</u>	
	<u>Age Yrs. mo's.</u>		<u>Age Yrs. mo's.</u>	
DF1	No record		5	3
DF4	5	2	8	3
DF5	5	-	8	-
DF7	No record		7	-
DM2	5	-	6	8
DM3	6	3	7	10
DM4	4	5	7	1
DM5	6	9	8	1
DM6	6	1	8	7
DM8	6	11	8	3
DM9	7	3	10	5*

*This patient was not available for records between 7/3 and 10/5.

These figures confirm in a general way the view that there is little, if any, growth of the anterior cranial base after about seven years, bearing in mind the range of individual variation that is to be expected. They support the use of De Coster's line for the superimposition of serial tracings after the cessation of growth in this area.

Cranial Base Angle.

In the deciduous dentition cases, as it was possible to define basion, the cranial base angle was taken as the angle made by the line Ba-S with the cranial base reference line. Nasion is described as "constant" if the cranial base line passes through it in serial tracings of the same individual.

The angle as defined above remained constant in all cases except one where it decreased 1° (Case DM6). As this was an isolated instance and the change was within the possible tracing error, it was not regarded as significant. (If all the cases had shown a change of 1° it would have been considered as probably significant despite being within the field of occasional error.)

Nasion was constant in 8 cases, moved above the line in two cases and below it in two cases.

Discussion.

In Part I the comparison of means for the cranial base angle measured by \angle Nasion-Sella Articulare, showed no significant difference between the means of

the dentitional groups. The findings of the individual serial studies confirms this picture and supports the view advanced in Part I that as an aetiological factor in medio-occlusion the cranial base angle is active before birth rather than afterwards. It was suggested earlier (Page 73) that Bjork's findings of individual changes in the cranial base angle with age, were perhaps related to variations in the vertical position of nasion which he considered constant. It will be seen from these findings that had true nasion been used in the serial tracings of these cases, the cranial base angle would have increased in two cases and decreased in two.

3. Growth changes in the mandible.

The general picture of growth and development in the deciduous dentition cases does not differ from that to be described in more detail for the mixed and permanent dentition serial studies. Two points of interest about mandibular growth were however noted. One was the more constant behaviour of the mandibular angle in the deciduous dentition cases as compared with that in the older groups which was variable in this respect. In the twelve cases observed, a reduction in the angle occurred in ten. The average decrease was 1.9° with a range of $1^{\circ} - 4^{\circ}$. In two cases no change was noted and there was no case showing an increase. This is too small a sample to form definite conclusions but the trend shown does

agree with the observations of Jensen and Palling (1954) referred to in Part I (Page 129). The other aspect already anticipated in discussing the mandible in Part I (Page 80), is the remodelling of the symphysis with the change from the deciduous to the permanent incisors, resulting in a more concave profile of the symphysis with apparently greater prominence of pogonion than of point B. This was noticed to a greater or lesser degree in the ten of the eleven cases with records covering the change of dentition. This change is brought about by alveolar remodelling and appears to be of a different nature than the increase in mental prominence to be described in some of the older patients. This latter process seemed to be more in the nature of a localised accretion to the chin rather than a remodelling of the alveolar process above it.

II. Treatment and Growth Changes in Cases Where Treatment was Started in the Mixed or Permanent Dentition.

Introduction:

The results of treatment in the 116 cases of mesio-occlusion whose treatment was started in the mixed or permanent dentitions are divided into two main groups, 97 "stable" cases and 19 "relapsed and other cases." The placing of stable in inverted commas is intended to emphasize the point that will emerge in the findings that the possibility of relapse is always present until growth has ceased. Follow up records are not yet complete for many of the so far successful treatments in the mixed dentition and stability cannot yet be claimed with certainty for some of these cases. The "relapse and other cases" group includes cases which did not respond to treatment or whose treatment relapsed or who were under observation only.

Individual case histories are not reported but cases are grouped according to the method of treatment and dentitional group but angular changes in individual cases are given in the appendix.¹ The angular changes after treatment are described in terms of mean angular changes for each appliance and dentitional group large enough to justify calculation. The angles considered and appliances used in treatment are indicated by the abbreviations given earlier. It will be seen from Table 31 which tabulates the number

¹ Section V.

of cases treated by the various appliances that the majority of the mixed dentition cases were treated by removable appliances while the permanent dentition cases were treated mainly by means of fixed appliances.

Table 31. Methods of Appliance Treatment in 97 "stable" cases of mesio-occlusion.

Appliance	TWA						
	URA	LRA	Funct.	CLIP	RIMT	OMT	Miscell.
Mixed Dent.	62	3	4	5	6	1	1
Perm. Dent.	4	1			8	1	1

Miscell. = combination of various methods: For key to other abbreviations see Pages 151-2.

The details of the appliance treatment are not described as the study is of the changes following treatment rather than of methods. Following the consideration of the angular changes in the successfully treated cases a general description of growth changes is given and a comparison is then made of the angular changes and the growth picture in a group of treated cases which have been stable over a number of years with the changes in the group of relapsed cases.

Findings.

The angles examined were those showing changes which were considered to be related to the appliance treatment. The angles have already been enumerated but they are repeated here for convenience:- Upper and lower incisor inclinations; the angles SNA and SNB expressed in terms of the \angle SNA - \angle SNB difference

- A/B difference. The angle of convexity, the Y Axis, the angles of the occlusal and mandibular planes to the cranial base and the mandibular angle.

The effect upon these angles of appliance treatment is best illustrated by a simple case, MM17 Plate 10, in which the immediate after treatment changes are as follows:-

	<u>Age</u>	<u>UI</u>	<u>LI</u>	<u>A/B</u>	<u>/Con</u>	<u>YAx</u>	<u>OP</u>	<u>MnP</u>
Before Treat.	10/3	88.5	88	-0.5	-3.5	64	21.5	29.0°
After Treat.	11/1	97.0	82	0.0	-3.0	66	17.5	30.5°
P.C.	0/10	+8.5	-6	+0.5	+0.5	+2	-4.0	+1.5°

P = time between records. C = change in angular measurement.

The active treatment consisted in the proclination of the upper incisors 8.5° and the other angular changes followed from this. The spontaneous retroclination of the lower incisor is typical and is probably due to lip pressure following the removal of the forward force from the reverse overbite of the upper incisor. The positive gains in the A/B difference, the angle of convexity, Y Axis and mandibular plane angle, result from the mandible not swinging so far forward and upward following the incisal correction. This is only a slight movement in this case and as only 0.5° is involved it could be considered within the limits of measuring and tracing error but the increase of +2° in the Y Axis tends to confirm that some change has occurred. The increase

of the mandibular plane angle 1.5° is a reflection of the same change. The decrease of the occlusal plane angle by 4° is due to the anterior determinant of the plane - the tip of the upper incisor - being moved forward and upward. It may be due also, in some instances, to vertical eruption of the upper molar which will also decrease the angle.

The angle of the occlusal plane is also affected by changes in the position of the upper first molar following the extraction of deciduous molars. Extraction of teeth may affect the incisal inclination as is seen in Case PF10 where following extraction of $\frac{5}{4}$, the upper incisal inclination was unaffected but $\frac{4}{4}$ the lower incisor retro-clined 6.5° . On the other hand Case MF39, Plate 11, shows a retroclination of the upper incisors of 7° following the extraction of $\frac{4}{4}$. Relapse however was already occurring in this case and it cannot be said that the premolar extraction was the sole or even the prime cause of the incisor relapse. Extractions of upper teeth in other cases have not been followed by retroclination of the upper incisors.

Treatment by U.R.A.

The picture of changes in Case MM17, whilst typical, is not by any means invariable as will be seen from table 32 which shows the mean changes in the angles considered in 62 cases treated by means of an U.R.A.

The range of the changes is quite large. They

do not give a strictly accurate picture of the initial changes following treatment because in some cases it was not possible to obtain after-treatment radiographs until some time after the appliance was removed and a greater or less amount of after treatment adjustment had occurred. The second column of means and ranges in Table 32 shows the after treatment changes as recorded in further follow up radiographs in 38 of the original 62 cases which vary in time from seven months to five years nine months later.

Table 32.

± Mean changes in angular measurement, A, in 62 mixed dentition cases treated by U.R.A..

A.	N=62			N=38	
	M ₁	R ₁		M ₂	R ₂
UI	+9.3	+ 2.0	to +19.5	+7.3	0.0 to +15.0
LI	-3.3	-12.0	" + 1.5	-3.6	-12.0 " + 1.5
A/B	+1.1	- 1.5	" + 3.0	+0.8	- 4.5 " + 2.0
∠Con	+1.6	- 0.5	" + 8.0	+0.7	- 5.5 " + 8.0
Y.Ax.	+0.9	- 1.5	" +4.5	+0.7	- 1.5 " + 4.0
O.P.	-2.8	- 9.0	" +2.0	-1.8	- 5.5 " + 2.0
MnP	+0.8	- 4.5	" +3.0	+0.3	- 4.5 " + 4.0

N = number of cases. M₁ = mean and R₁ = range of changes after treatment (62 cases). M₂ = mean and R₂ = range of later after treatment changes in 38 of the 62 cases. Average time between M₁ and M₂ = 2.3 years. Range = 7mths. to 5yrs. 9mths.

The immediate after treatment mean changes show a proclination of the upper incisor +9.3° and retroclination of the lower -3.3 . The extreme figure of

+19.5° was in a case (MM4), where the upper incisor was retroclinated at 86.5° before correction. The extreme retroclination of -12° for the lower incisor was in a case (MF8) where the upper central incisors were occluding between the lower centrals and laterals aggravating the proclination of the former which therefore corrected a more than average amount.

The average positive increase in the A/B difference of +1.1° and in the angle of convexity of +1.6° together with the opening of the Y Axis of between 0.9°, have been explained in the discussion of changes in Case MM17. The minus values in the range of values for the A/B difference, angle of convexity and Y Axis, may be due to adverse growth changes as for example in Case MF27, where there was a treatment time of 6 months but an interval of 1 year 9 months between tracings. The angular changes of -1.5° and -1.0° in the A/B difference and angles of convexity in this case, reflect an unfavourable growth trend, maxillary growth being downwards and mandibular growth downwards and forwards, over the period in question.

The occlusal plane shows an average change of -1.8° with a range of -9° to +2°. The change of +2° seen in the range for the occlusal plane was from Case MM12 where there was an interval of 2 years 9 months between tracings. In this, as in the majority of mixed dentition cases, allowance has to be made for the mesial drifting of the upper first molars as it was the

exception for a patient to present without premature loss of one or more deciduous molars. The Y Axis and mandibular plane vary in the same direction with means of $+0.7^{\circ}$ and $+0.8^{\circ}$ respectively. The large positive values in the range of $+4.5^{\circ}$ and $+3^{\circ}$ are associated with abnormal paths of closure of the mandible from rest to occlusion before treatment.

The mean values of the angular changes in the 38 cases where follow up records were obtained (Table 32) showed a tendency for the initial proclination of the upper incisors to decrease although increases occurred in individual cases. The lower incisors showed a change to increased retroclination by a small fraction, again with individual variations. The trend to increased mandibular prognathism seen in the Class III material as a whole in the study of mean growth changes in Part I is shown in the decrease to 0.7° of the mean positive gain of $+1.6^{\circ}$ in the angle of convexity present immediately after treatment. The angle of the Y Axis has decreased more often than it has increased and the occlusal and mandibular plane angles have behaved similarly.

There is a general tendency for the angles to alter in the direction of the original angles but with marked individual variations some of them increasing the changes. As the study of the growth changes in the jaws in the "stable" and "relapsed" cases will show, the angular changes, apart from the immediate after treatment changes, are largely a reflection of

growth changes in jaw relationships and it does not appear as if the effects of appliance treatment will alter an unfavourable growth pattern. It is possible, but difficult to prove, that treatment may influence the growth pattern favourably in border line cases. Cases treated by U.R.A are illustrated in Plates 10-14.

Consideration was given to an examination of the question whether the treatment results differed in cases in Groups A, B, and C. (Part I). It was not thought that they would as the classing of a case as Group A, B, or C does not give an exact indication of the degree of antero-posterior malrelationship which is more accurately judged by the A/B difference. A group A case for example in which the maxillary prognathism was exactly -1SD and that of the mandible exactly +1SD, would show a greater discrepancy than a Group B case where the prognathism of the maxilla was exactly +1SD and that of the mandible was just over +1SD. To confirm the assumption that no difference would be seen, the mean degrees of upper incisal proclination were calculated for the Group A, B and C cases in the 62 mixed dentition URA cases in Table 32. The results were as follows:-

	<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
UI Mean proclination	9.3° N=37	9.6° N=19	8.7° N=6

and show no significant difference between the groups.

Functional Appliances.

There were four cases, two treated with a reverse

Andresen and two with a Bimler functional appliance, (Plate 16). The proclination of the upper incisors was much less than in the U.R.A. cases ranging from $+1^{\circ}$ to $+7^{\circ}$. Lower incisal retroclination was similar to that in the U.R.A. group varying from 0° to -10.5° . Follow up records in three cases $3\frac{1}{2}$ - 4 years later, showed little change in the lower incisors with increases in upper incisal angulation in two cases. The angle of the Y Axis increased in all cases but the follow up cases showed a decrease in the before treatment angle in two cases and a modified increase in the third. The changes in the occlusal and mandibular planes did not differ from these in the U.R.A. group.

Cast Lower Inclined Plane. (C.L.I.P.)

This appliance which is cemented to the lower anterior teeth was used in 5 cases, in one case because of lack of co-operation by a child who would not wear a removable plate as instructed and in the others because of the premature loss of some or all of the permanent first molars. The incisal angle changes were similar to those in the U.R.A. and Functional Appliance group; the increases in the proclination of the upper incisor were from $+4^{\circ}$ to $+13^{\circ}$ and the retroclination of the lower incisors varied from 0.5° , which represents no real change of inclination, to -12° . The changes in the other angles were within the ranges of those in the U.R.A. group. Three cases were followed up, two for 2-3 years and the third for

four years. Upper incisal proclination increased in all three cases and lower incisal retroclination increased markedly in one case and decreased in another. The A/B difference, angle of convexity and Y Axis showed positive gains in two cases reflecting a favourable growth trend and negative increases in the third, which, despite the unfavourable trend, has been stable for four years. This last case MF36, was also of interest because at the original consultation the first permanent molars were present but when called up for treatment all molars had been extracted and the patient presented the typical picture on which is based the "bite of convenience" theory of the cause of mesio-occlusion and it may be said that no evidence to support this theory was found in this study. A patient treated with a cast lower inclined plane is shown in Plate 17.

Lower Removable Appliances.

This appliance was used in cases where either the upper or lower incisors or both, showed proclination before treatment as in Case MM24, (Plate 18), where both the upper and lower incisors appeared to be excessively proclinated. The results in the three cases are of interest. In Case MM24, retroclination of the lower incisors 10° was followed by 8° spontaneous retroclination of the upper incisors, negative increases of 1.5° in the angles of convexity and A/B difference and increases in the angles of the

occlusal and mandibular planes. Five years later the upper incisor was 6° retroclinated from its original position, whilst the lower incisor had returned to its original degree of proclination.

In case MM38, where there was a tongue thrusting habit on swallowing, the lower incisors were retroclinated 4° and the upper incisors proclinated 3° . There were slight negative increases in A/B difference and angle of convexity, while the angles of the Y Axis, occlusal plane and mandibular plane followed the U.R.A. group trend. The follow up two years five months later shows the incisors about halfway back to their original positions.

In the third case MM59, the lower incisors, which were widely spaced, were retroclinated 10° and the upper incisors came forward $+16^{\circ}$, which was a larger change in proclination than occurred in many cases where the incisors were proclinated by an appliance. It must be assumed that the lower incisors were forcing the upper incisors palatally and that they were moved forward by tongue pressure on removal of the lower incisor pressure. The follow up three years eight months later showed the upper incisors relapsed slightly to $+12.5^{\circ}$, the lower incisors remaining stable.

In all three cases the angle of the Y Axis had increased in the follow up tracings, 2.5° to 3° and the occlusal plane showed a trend back to its original angle.

Combination of Appliances.

Two cases were treated by appliances to proclinate the upper and retroclinate the lower incisors and both show large initial changes in inclination of both incisors, (Plate 19). The follow-up examination two years later show in one case some relapse of the upper incisors and increased proclination of the lower, whilst the other case showed the reverse picture.

(Observations on Extractions in Mixed Dentition Cases.

The problem of extractions did not arise in mixed dentition cases where early treatment was possible as, frequently, deciduous teeth had been lost prematurely and the premolars had yet to erupt. In a few cases deciduous canines were extracted in the upper arch to provide space for the alignment of the permanent incisors and in the lower arch to encourage lingual movement and retroclination of the permanent incisors. Premolar extractions were carried out later in many cases that attended for follow up studies as crowding developed with the eruption of the canines and premolars. These however were not primarily problems in the appliance treatment or in the analysis of the changes following treatment and so this has not been discussed in any detail here.)

Fixed Appliance Treatment.

The Johnson Twin Wire Arch with Reverse Inter-maxillary Traction:- This form of treatment was only found necessary for six patients who had not

responded to simpler forms of treatment or who were in a late stage of the mixed dentition with crowding developing in the canine-premolar region. In three cases antero-posterior expansion of the upper arch with compressed helical coil springs was carried out in addition to the intermaxillary traction. This has the double effect of creating space for the canines and premolars and of proclinating the upper incisors. Extraction of four second premolars was necessary in one case and of lower first premolars in another case. Table 33 gives the mean changes in the angular measurement in 6 cases immediately after treatment. Later records were available for five of these cases.

Table 33.

± Mean changes in angular measurements (A) in 6 mixed dentition cases treated by T.W.A. + R.I.M.T..

Appliance		T.W.A + R.I.M.I.			
A	N = 6		N = 5		
	M ₁	R ₁	M ₂	R ₂	
UI	+8.3	+2.0 to +15.5	+8.3	+1.0 to +12.5	
LI	-6.3	-3.0 " - 9.0	-8.0	-3.5 " -11.5	
A/B	+1.6	0.0 " + 3.5	+0.9	-0.5 " + 2.0	
∠Con	+1.7	-1.5 " + 5.0	+1.3	-2.5 " + 5.0	
Y.Ax.	+1.3	-0.5 " + 4.0	+0.5	-2.0 " + 3.0	
O.P.	-3.0	-6.5 " - 1.0	-3.9	-6.0 " - 3.0	
MnP.	+1.7	-1.0 " + 4.0	-0.6	-3.5 " + 4.0	

N = No. of cases. M₁ and R₁ = mean and range of changes after treatment. M₂ and R₂ = mean and range of later after treatment changes. Average time between M₁ and M₂ = 2.4 years range 1-4yrs.

The average increase in proclination of the upper incisor was $+8.3^{\circ}$ and in retroclination of the lower incisor -6.3° . Individual cases showed variations of from $+2^{\circ}$ to $+15.5^{\circ}$ for the upper incisor and of from -3° to -9° for the lower incisor. The alterations in the other angles showed a similar range to the U.R.A. group. Follow up records in five cases showed no change in the mean value for upper incisal inclination, all cases being relatively stable. The mean value for lower incisal retroclination increased to -8° , three cases were relatively stable and two showed increased retroclination. The individual and mean changes for the other angles resemble those for the U.R.A. group, the decrease in positive mean increases for the A/B differences, angle of convexity and Y Axis between the first after treatment and final tracings reflecting a relative increase in mandibular prognathism. Plates 20 and 21 illustrate treated cases.

Permanent Dentition Cases.

There were 15 "successful" cases. Of these 8 were treated by fixed appliances, 4 by U.R.A. and 1 by a L.R.A., 1 by a combination of a L.R.A. and an Upper Fixed Appliance and 1 by Occipito-mental Traction.

Fixed Appliance Cases.

Six cases were treated by intermaxillary traction. In four of these, extractions were carried out in both arches followed by retraction of the lower

incisors and canines. Two cases were also treated by Antero-posterior expansion of the upper arch with a Johnson Twin Arch and helical coil springs.

Table 34 gives the mean changes in angular measurements.

Table 34.

+ Mean changes in angular measurements (A) in 8 permanent dentition cases treated by T.W.A. + R.I.M.T.
M = mean. R = range. N = number of cases.

Appliance		T.W.A. + R.I.M.T.
A.	M.	R (N=8)
UI	+5.3	+0.5 to +9.5
LI	-6.4	-1.0 " -2.5
A/B	+0.8	0.0 " +2.0
∠Con	+0.9	-1.0 " +3.5
Y.Ax.	+0.7	-1.0 " +2.0
O.P.	-3.3	0.0 " -6.0
MnP	+0.3	-1.0 " +1.5

The mean angular change in upper incisal proclination of $+5.3^{\circ}$ was less than in the mixed dentition fixed appliance or U.R.A. groups. The mean value for lower incisal retroclination was -6.4° but this value is heavily influenced by a marked over retroclination of -25° in one case, PM19 (Plate 22). Removing this figure gives a mean of -3.7° similar to that for the U.R.A. groups and less than that for the

fixed appliance mixed dentition cases. The combined effect of proclination and retroclination in the permanent dentition is less than that in the mixed dentition groups apart from the results in the Functional Appliances group. The changes in the other angles resemble those of the U.R.A. group. Follow up records were available in only two cases which presented no features of interest except in the case of PM19, where the lower incisor retroclination of -25° had relapsed -3.5° , leaving a net gain in retroclination of -16.5° .

Upper Removable Appliance Cases.

Four cases were treated by this method. One is illustrated in Plate 23. The mean value for upper incisal proclination was $+10$ and for lower incisal retroclination -2.5° .

In the lower jaw, as regards retroclination of the incisors, one case showed no change and increases of -0.5° , -4.5° and -5° occurred in the other three. Before analysis of the permanent dentition cases it had been thought by the writer that the spontaneous retroclination of the lower incisors observed in the mixed dentition cases would not be found to the same extent in the permanent dentition. In the mixed dentition the four lower incisors were often standing alone or with only the canines to support them and thus would be more easily moved by lip pressure than in the case of the permanent dentition

with a complete arch of mutually supporting units. The results such as they are do not support this idea.

The remaining cases PF40, (L.R.A.) Plate 24, P.F.38 (Removable plus fixed upper lingual arch with finger spring) and PF24 (O.M.T.), present no features of interest except case PF24, as a successful treatment by Occipito-mental Traction which showed changes of $+5^{\circ}$ for the upper incisor and -2.5° for the lower incisor together with large positive increases in the A/B difference, $+3^{\circ}$, angle of convexity $+6.5^{\circ}$, and Y Axis, $+2.5^{\circ}$. This was not a functional protrusion case as the figures might suggest, there being no change in the molar relationship and a "hinge closure" before and after treatment from rest to occlusion. The reason for the changes appears to lie in the marked vertical alveolar development seen in the upper molar region and to a lesser extent in the lower incisor region, indicating overclosure before treatment with marked upward and forward travel of the chin.

Summary.

1.Changes following appliance treatment.

The effects of appliance treatment when evaluated by an analysis of the angular changes following appliance treatment in 97 cases of mesio-occlusion irrespective of the method of treatment, differed only in degree and showed the same general picture which was as follows:-

An increased proclination of the upper incisors and an increased retroclination of the lower incisors. There were positive increases in the A/B difference and angle of convexity, usually shown as a reduction in the negative values for these angles. The angles of the Y Axis and mandibular plane were increased and the angle of the occlusal plane was decreased. Follow up studies in 57 of the cases treated, showed on the average a high degree of stability as regards the alterations in the upper and lower incisal inclinations, but there was a trend to a return to the before treatment values in the other angles. The A/B difference showed less average relapse than the angle of convexity reflecting a relatively greater increase in basal than alveolar mandibular prognathism which agrees with the findings on growth in Part I.

Individual cases varied in the direction of change after treatment which is the resultant of the amount and direction of growth. Some cases showed continuing increases in the angular changes resulting from treatment whilst others showed little change or a return to the before treatment values or even a change in the opposite direction. These individual variations show that the basic pattern of growth has not been altered by appliance treatment and that where this is unfavourable it will nullify any improvement in mandibular position effected as a result of the occlusal re-adjustment. This is not to deny the

helpful influence of treatment when the growth pattern is basically favourable. The influence of growth upon the stability of the changes effected by appliance treatment is considered more fully in the section III where a comparison is made between stable cases and cases that have relapsed. Occlusal changes were the correction of the reverse overjet and overbite and approximately one case in five showed an improved molar occlusion which implies that in the majority of cases there was no functional protrusion of the mandible.

2. Summary of changes due to growth.

Observations have already been made on some of the changes due to growth in the case reports in the deciduous dentition cases. The general picture obtained of facial growth by superimposition of serial tracings on the cranial base reference line is of a downward and forward movement of both jaws relative to the cranial base, with increases in the vertical height and antero-posterior depth of the face. Individual cases vary both in the amount and general direction of growth. In the majority of cases a constant angular relationship is maintained between the maxillary plane and the cranial base although individual variations were seen. The occlusal and mandibular planes vary following occlusal adjustment and a decreased degree of closure of the mandible. Changes in the direction of mandibular growth as

indicated by alterations in the angle of the Y axis also occurred independently of any increase that might be shown immediately after treatment due to occlusal changes.

Superimposition of the maxillary and mandibular outlines by the methods described showed the same individual variation in amount and direction of growth as was seen in the overall picture. Maxillary growth was forward (or horizontal) with a variable amount of increase in alveolar molar, and alveolar incisal, height. The vertical descent of the maxilla as seen in the overall picture occurs mainly because of growth above the level of the maxillary plane which descended in relation to the cranial base. The mandible showed increases in the horizontal direction in the body of the mandible and increases in vertical height from the condyle to the angle. Localised remodelling of the symphysis was seen in several cases producing a greater prominence of the base of the chin relative to the alveolar region of the symphysis. This remodelling is referred to as "symphyseal accretion", and as mentioned earlier, differed from the remodelling seen in the deciduous dentition cases. The mandibular angle was unchanged in some cases and increased or decreased in others, changes of from -6.5° to $+3.5^{\circ}$ being recorded. The majority of cases showed marked vertical alveolar growth in the molar and incisor regions. The various

combinations of maxillary and mandibular growth patterns can be seen in the tracings of the cases in the illustrative plates of treated cases in the appendix. Section III.

III. A comparison of the treatment and growth changes in a series of relapsed cases with those in a series of successfully treated cases.

The 19 cases which relapsed or were unsuccessfully treated have been analysed and compared with ten successfully treated cases of which half have been stable for over five years, four for over four years, and one for nearly four years. The purpose of the comparison being to try and determine the treatment and growth factors that make for stability or relapse or failure in treatment. In this latter respect, as already noted, there were nine cases in the clinical material which were adjudged untreatable by Orthodontic means and which were referred to the Oral Surgeon for advice as to the possibilities of surgical correction. These cases have not been discussed as it was thought more profitable to examine the cases which were judged clinically to be treatable by Orthodontic means but which turned out to be untreatable or in which partial success only was achieved.

The cases under the heading "Relapsed" consisted of :-

1. C.R. cases which had been successfully treated and were stable for a period before relapsing completely.
2. P.R. successfully completed cases which were stable for a time and then partially relapsed to a stable position.

3. U.S. cases in which treatment was unsuccessful despite the patient's co-operation.

4. O. cases which were under observation only and showed an increase in the degree of mesio-occlusion.

The number of cases in each category was:-

C.R. 9, P.R. 5, U.S. 2, and O. 3.

The cases were compared by tabulating the following data:-

1. The A, B, C, group ("differential analysis")
Part I.
2. The age at the first and final examinations and the period of observation.
3. The method of appliance treatment.
4. The original A/B difference, the angle of convexity and the angle of the Y axis.
5. Angular changes during the period of observation. These are recorded as the difference between the original measurement and the last recorded measurement - the net angular change.

The results are shown in Table 35, stable cases, Table 36, female relapse and Table 37 male relapse cases. Table 38 compares the mean net angular changes in the stable and relapse groups. Stable cases are illustrated in Plates 13, 18 and 21. Relapse cases are illustrated in Plates 11 and 25-28.

Table 35.

Data for 10 Stable Cases. I.G. and F.G. = Initial and Final ABC grouping. I.A. and F.A. = Initial Age and Final Age. P.O. = Period of Observation. App. = Appliance employed. Orig. = Original.

Key to abbreviations for angles and appliances given earlier in text.

Case No	MF1.	MF4.	MF8.	MF37	MF43	MF48	MM24	MM21	MM36A	MM56
1. I. Group	A	B	B	A	B	A	A ¹	A	B	A
F. Group	No change.									
2. I.A.	7/-	8/9	8/2	9/2	9/11	8/11	8/-	7/10	8/8	11/1
F.A.	11/1	13/D	13/8	13/9	14/8	14/3	13/6	13/1	13/5	16/3
P.O.	4/1	5/1	5/6	4/7	4/9	5/4	5/6	5/3	4/9	3/8
3. App.	CLIP	URA.	R.A.	URA.	URA.	URA.	LRA.	TWA.	URA.	TWA.
4. Orig. A/B	-3.5	0.0	-2.0	+0.5	-2.0	+1.0	+1.5	+1.5	-1.5	-4.5
" /Con.	-4.0	-1.5	-3.0	-1.5	-3.0	+2.0	+3.5	+3.5	-3.5	-7.0
Y Axis	63.0	64.5	60.0	66.0	63.5	67.0	62.5	60.0	61.0	63.0
5. Net changes in angular readings between I.A. and F.A.										
U.I.	+13.0	+7.5	+4.5	+5.0	+14.5	-3.3	-6.0	+12.0	+10.0	+12.5
L.I.	-2.5	-2.0	+0.5	-4.0	-9.0	-4.0	-0.5	-10.5	-7.5	+1.5
A/B	+4.5	+1.5	+1.5	-2.0	-1.0	+3.0	-1.5	-1.0	0.0	+0.5
/Con	+5.0	-2.5	+0.5	-5.5	-5.0	+3.0	-0.5	-3.5	+0.5	-2.0
Y Ax.	0.0	-1.5	-1.0	0.0	-0.5	+3.0	+3.0	+0.5	+0.5	+3.0
O.P.	-4.0	-5.0	-2.5	-2.5	-2.5	+1.5	+0.5	-3.0	-3.0	-3.5
MnP.	-4.0	-3.0	-4.5	-2.0	-3.5	+1.5	+0.5	0.0	-1.5	+1.0
Mn/	-1.5	-4.0	-2.5	-5.0	-3.5	+3.5	0.0	-1.5	+1.0	0.0
MxP	0.0	+1.0	-0.5	+1.0	-0.5	+1.5	+3.0	-1.0	+3.0	+2.0

Note: ¹ A+ = Mx > +1SD Mn > +1SD.

Table 36.

Data for nine relapsed cases (female). I.G. and F.G. = Initial and Final ABC grouping. I.A. and F.A. = Initial age and Final age. P.O. = Period of Observation. App. = Appliance employed. Orig. = Original. Key to abbreviations for angles and appliances and degree of relapse given earlier in text.

Case No	MF10	MF13	MF18	MF22	MF39	MF55	MF66	PF7	PF31
Relapse	C.R.	C.R.	0	P.R.	C.R.	U.S.	P.R.	C.R.	C.R.
1. I.G.	B	B	B	B	B	B	B	A	B
F.G.	B	B	B	B	B	B	B	A	B
2. I.A.	7/3	9/11	13/-	10/10	8/2	8/10	8/3	9/11	8/9
F.A.	13/2	13/1	16/-	16/2	13/7	12/8	13/7	15/3	14/7
P.O.	4/11	3/2	3/-	5/4	5/5	3/10	5/4	5/4	5/10
3. App.	URA.	U.R.A.	O.	H.R.A	URA.	OMT.	URA.	URA.	LRA.
4. Orig. A/B	+1.5	-4.0	0.5	-5.5	-1.0	-4.0	0.0	+0.5	-3.5
" / Con	+7.0	-9.5	-4.0	-14.0	-5.5	-9.0	-2.0	0.0	-9.0
" Y Ax.	63	63	65	66	63.5	60	63	68	59
5. Net changes in angular readings between I.A. and F.A.									
U.I.	-3.0	+9.0	+5.0	+1.5	-2.0	+3.5	+10.0	+3.5	+3.0
L.I.	+3.5	-2.0	-1.0	-5.0	-6.5	-6.0	-2.0	-11.5	-6.5
A/B	-0.5	-1.5	-2.5	-1.0	-3.0	-2.0	-4.0	-3.5	-2.0
/ Con	-3.5	-5.5	-5.0	-3.0	-5.5	-5.0	-9.0	-9.5	-5.0
Y Ax.	0.0	+1.5	-1.5	-0.5	-1.0	-0.5	-1.0	-1.5	-3.0
O.P.	-1.0	-1.0	-2.0	-3.5	-6.0	-2.0	-1.5	-0.5	-8.5
MnP	-3.0	+1.5	0.0	-3.5	+2.0	+3.0	-2.0	-1.5	-3.5
Mn/	-3.0	0.0	-1.5	-2.0	+2.5	-0.5	-4.0	0.0	-4.0
MxP	-0.5	-1.0	+1.0	+0.5	+0.5	-1.0	+2.0	+2.5	+1.5

Table 37. Data for 10 relapse cases (male). I.G. and F.G. = Initial and Final ABC groups. I.A. and F.A. = Initial Age and Final Age. P.O. = Period of Observation. App. = Appliance employed. Orig. = Original. Key to abbreviations for angles, appliances and degree of relapse given in earlier text.

Case No.	MM11	MM18	MM22	MM29	MM33	MM43	MM62	PM5A	PM8.	PM11
Relapse.	C.R.	O.	U.S.	O.	P.R.	C.R.	P.R.	C.R.	C.R.	P.R.
1. I.G.	A _{Mx-2}	A	A	B	B	A	A	A	A+ ¹	B
F.G.	Mn+	A	B	B	B	A	A	B	B	B
2. I.A.	10/8	10/8	13/7	11/5	9/1	7/10	10/4	14/4	14/4	13/7
F.A.+	15/3	13/4	17/8	14/6	13/8	13/1	15/4	17/9	17/2	17/9
P.O.	4/7	2/8	4/1	3/1	4/7	5/3	5/-	3/5	2/10	4/2
3. App.	URA.	O.	RIMT	O.	URA.	URA.	RIMT	RIMT	RIMT	RIMT
4. Orig. A/B	-0.5	+1.5	-1.5	-2.5	-2.0	-1.0	-1.5	-3.0	-4.0	-2.5
∠Con.	-4.0	+2.5	-4.0	-11.5	-5.0	-1.0	-4.0	-8.0	-12.0	-7.0
Y Ax.	69.0	75.0	68.0	67.0	61.0	64.0	70.5	65.5	64.0	68.5
5. Net changes between I.A. and F.A. in angular readings.										
U.I.	-7.5	+5.5	+6.0	-4.0	0.0	-1.0	+10.0	-2.0	+3.5	+6.5
L.I.	-1.5	+6.5	-4.0	0.0	-1.5	-9.5	-5.0	0.0	-8.0	0.0
A/B.	-4.0	-0.5	-3.0	-0.5	-1.5	0.0	-0.5	-2.0	-3.5	-0.5
∠Con.	-10.0	-2.5	-8.0	-2.5	-2.5	-1.0	-2.5	-7.0	-7.0	-1.5
Y Ax.	-2.0	+0.5n	-2.0	-0.5	-2.0	+3.5	-1.0	-0.5	0.0	-1.0
O.P.	+6.5	-2.0	-6.0	+8.5	+1.5	-2.5	-6.0	-2.0	-1.0	-10.5
MnP	-2.0	+1.0	-13.5	-0.5	+0.5	-5.0	-2.5	-3.0	0.0	-2.0
Mn/	+1.5	+0.5	-0.5	-2.0	-2.5	+3.0	-1.0	+1.0	+1.0	+0.5
MxP	+2.0	0.0	-1.5	+1.5	0.0	-2.5	-0.5	+1.5	-1.0	-1.0

Note: ¹ A+ = Mx >+ 1SD. Mn >+ 1SD: ² Mx-Mn+ = Mx <-1SD Mn >+1SD

Table 38.

Mean net angular changes in 10
Stable (S) and 19 Relapse (R) cases over
the period of observation, P.O..

	U.I.	L.I.	A/B.	∠Con	Y Ax	O.P.	MnP.	Mn∠	MxP.
S (10)	+6.9	-5.0	+0.5	-1.0	+0.7	-2.1	-1.2	-1.3	+0.9
R (19)	+2.4	-3.0	-1.2	-4.8	-0.6	-2.0	-1.7	-0.5	+0.2

Findings.

Comparison of Mean Net Angular Changes.

The incisal changes are smaller in the relapsed group. The A/B difference shows a mean negative increase of -1.2° compared with a mean positive increase of $+0.5^{\circ}$ in the stable cases. The most marked difference is in the mean angle of convexity which has increased -4.8° in the relapsed group compared with -1.0° in the stable group. The Y axis shows a slight positive change in the stable group and a slight negative change in the relapsed group. The occlusal plane angle, mandibular plane angle and the mandibular angle all show a decrease of varying degree in both groups. The maxillary plane angle shows a positive change in both groups greater in the stable group but both under 1° .

As in all the other comparisons made of the material in this study, the picture given by the mean values of a measurement for any group is contradicted in one respect or another by the individuals making up the group. The mean value of any character measured is comparable to Ideal Normal Occlusion, a useful fiction not to be confused with reality. It is true that individuals will be found displaying the mean value for one or two measurements but to find any number of mean values occurring in one individual is highly improbable. It is the combination of all the variations in the parts and relationships

measured that produce the individual pattern in all its infinite variety.

A study of the individual cases brings this out. The one consistent feature in all the relapse cases is a negative increase in the angle of convexity varying in degree. For any other value examined there is always at least one individual who does not conform to the general pattern. This applies as much to the stable cases as to the relapsed group. Cases MF43 (Plate 13) and MF48. have both been stable for over 4-5 years and show no signs of relapse, having come safely through the pubertal growth spurt. The net angular changes in these cases are in marked contrast. Except for an increased retroclination of the lower incisors in both cases, every other angle shows an opposing value.

The consistent negative increase in the angle of convexity in all cases in the relapse group was regarded as the most significant finding pointing to an increase in mandibular basal prognathism relative to maxillary prognathism as the primary factor in relapse. This increase in mandibular prognathism relative to maxillary prognathism with age, is, as has been mentioned, a feature of normal facial growth, Bjork (1947), Lande (1952). It prompts the suggestion that the fault in Class III relapses is an exaggeration of a normal trend (Braccesi and Lucchese 1958) produced either by excessive mandibular growth or by normal mandibular growth and deficient maxillary growth.

These possibilities were investigated by firstly comparing the A, B C grouping (Differential Analysis Part I) of the Relapsed and Stable cases at the beginning and end of the observation period and secondly by the study of growth in individual stable and relapsed cases by means of the superimposition of serial tracings.

The A, B, C group assessment showed in the stable group, 6 group A (female 3, male 3), 4 group B (female 2, male 2) with no change in individual grouping over the observation period. In the Relapse cases the initial grouping was:- Female; 1 Group A, 8 Group B and Male; 7 Group A, 3 Group B. Classification at the end of the observation period showed that in the females no individual had changed groups but in the males three Group A cases had become Group B cases and one (Case MM11, Plate 26) fell into the extreme group of maxillary-mandibular malrelationship (Part I Page 102) making the distribution 3 Group A, 6 Group B and 1 Group, "Maxilla $\langle -1SD$ and Mandible $\rangle +1SD$ ". These findings confirm the clinical impression already mentioned as to a greater incidence of Group B cases in the female mixed dentition group in this study and more important it confirms the pointer given by the comparison of the means in the relapse and stable groups to a relative increase in mandibular protrusion being the cause of relapse. This of course does not rule out maxillary deficiency as a

contributory factor. The female relapse cases already showing a mandibular protrusion (Group B) initially could not necessarily be expected to show any further change of group if maxillary growth is still sufficient to keep the degree of maxillary prognathism within $\pm 1SD$. On the other hand four of the seven male Group A cases showed a worsening in maxillary-mandibular relationships marked enough to be detected by the relatively coarse standard of $\pm 1SD$.

An examination of the before treatment measurements for A/B difference, angle of convexity, angle of the Y axis and degree of reverse overjet and overbite failed to show any consistent difference between the stable and relapse group or between the different categories of "relapse" within the relapse group. There was nothing in the angular measurements to differentiate for instance between the case that was corrected and stable for 3 years and then relapsed and the case which was corrected with great difficulty and relapsed immediately.

Consideration is therefore given to the amount and direction of growth in individual cases in the stable and relapse groups to see if these factors are the causes of success or failure.

Growth Changes in Stable Cases.

These are the cases shown in Table 35 together with other illustrative cases. For convenience, ages in years and months are indicated as in the tables; e.g. 6/4 = six years four months.

Case MF1.

Growth record: 7/0 - 8/4, slight general increase both jaws. 8/4 - 9/10, more marked growth. 9/10 - 11/1, little change. The general picture is of downward and forward growth with maxilla and mandible showing proportionate increases.

Case No. MF4.

8/9 - 11/10, marked forward growth of the maxilla and mandible. 11/10 - 13/10, slight forward growth of the maxilla with mandibular growth more vertical than forward with reduction of the overbite. The angle of convexity has increased due to accretion at the symphysis.

Case No. MF8.

8/2 - 11/1, marked maxillary and mandibular growth. 11/1 - 13/8, slight growth in either jaw in marked contrast to the first period.

Case No. MF37.

9/2 - 12/5, moderate amount of maxillary and mandibular growth. 12/5 - 13/9, moderate maxillary growth with more marked mandibular growth with an increase in negative A/B difference but the occlusion remained stable.

Case No. MF43. (Plate 13)

9/11 - 12/8, proportionate maxillary mandibular growth. 12/8 - 14/8, slight maxillary growth with fairly marked mandibular growth forwards and vertically. Despite this unfavourable trend shown

by the marked negative increase in the angle of convexity, the occlusion remained stable, a factor in the stability of the case may be the amount of backward displacement of articulare.

Case No. MF48.

8/11 - 11/10, maxillary growth forward and mandibular growth more downward than forward. 11/10-14/3, very slight maxillary growth with some mandibular growth but markedly less in either, compared with the first period. The pattern in this case contrasts sharply with the previous case MF43, the angle of convexity showing a positive gain of 3.5° .

Case MM24 (Plate 18).

8/0 - 11/10, proportionate growth in both jaws more vertical than horizontal in the mandible. 10/10 - 13/6, slight growth in both jaws with marked vertical mandibular growth.

Case No. MM21.

7/10 - 11/5, general growth of both jaws but greater in the mandible. 11/5 - 13/1, no perceptible maxillary growth, some mandibular growth downwards and forwards.

Case MM36A.

8/10 - 13/5, slight growth in both jaws. 10/4-13/5, marked growth proportionate in amount in both jaws.

Case No. MM56. (Plate 21).

11/1 - 13/0, little change noted. 13/6 - 16/3,

marked growth in both jaws.

Growth picture in illustrative cases not included in the series of 10 stable cases in Table 35.

Case No. MM59. (Plate 16).

10/3 - 14/3, proportionate growth of maxilla and mandible with mandible showing more backward than forward placement.

Case No. MM17. (Plate 10).

10/3 - 14/2, proportionate growth both jaws with some backward placement of articulare, symphyseal remodelling.

Case No. MM61. (Plate 20).

10/5 - 13/11, slight growth in either jaw and little backward displacement of articulare compared with MM17 (Plate 10).

Case No. PF3. (Plate 25).

No obvious growth 15/3 - 16/6.

Case No. PF40. (Plate 25).

Slight growth 13/4 - 17/0.

Case No. PM19. (Plate 22.). Growth increments 16/4-19/10.

Growth Changes in Relapse Series.

1. C.R. Cases showing complete relapse.

Case No. MF 10.

Correction stable 7/3 - 11/0 (approx.) relapsed between 11/0 - 12/2. Tracings 7/3 - 9/6 show slight growth of maxilla with marked downward and forward growth of the mandible.

Case No. MF13. /

Case No. MF13.

9/11 - 10/9, slight growth in either jaw.
10/9 - 13/1, slight maxillary forward growth, marked mandibular growth downwards and forwards associated with relapse.

Case No. MF39, Plate 11.

8/6 - 11/6, general maxillary and mandibular growth, correction stable from 9/1 - 11/6. 11/6 - 13/7, very slight maxillary growth, the mandible shows continual downward and forward growth with marked accretion at the symphysis. Incisor occlusion relapsed.

Case No. MM43.

There was a previous history of correction and relapse by the patient's own dentist. Recorrected by age 8/6, relapsed again to an edge to edge bite by the age of 10/10. Growth: 7/10 - 10/10, moderate maxillary growth with more marked mandibular growth vertical and forwards. 10/10 - 13/1, slight maxillary growth with marked mandibular growth. The mandibular angle opened 3° without any marked posterior movement of articulare and therefore the increase in overall length due to this was felt mainly anteriorly. The bite relapsed from edge to edge to a reverse overjet and overbite.

Case No. PM8.

Correction followed by quick relapse. 14/4 - 17/2, negligible maxillary growth moderate mandibular

growth, less from 16/5 - 17/2 than from 14/4 - 16/5.

Case PM5A.

Incisal occlusion corrected and stable 13/3 - 14/4; post-treatment cephalometric records only were available and show the following growth picture:- 14/4 - 16/7, forward maxillary growth, mandibular growth more vertical than horizontal but the resultant was more forward growth than in the maxilla with relapse of the incisor overbite. 16/7 - 17/9, negligible maxillary growth, mandibular growth slight presenting a similar picture to Case PM8.

Case No. PF7. (Plate 27).

9/11 - 11/11, moderate growth both jaws. 11/11 - 14/2, moderate maxillary with marked mandibular growth associated with relapse. 14/2 - 14/3, no maxillary growth, slight vertical mandibular growth.

Case No. PF31. (Plate 25).

Stable after correction from 9/6 - 11+, having relapsed by 12/6. The radiograph at 8/9 was not taken in the cephalometer and cannot be used for linear comparisons. 12/6 - 14/7, slight maxillary forward growth compared with mandibular forward growth, which itself is not marked, suggesting that the main spurt in mandibular growth occurred before 12/6.

Case No. MM11. (Plate 26).

Treatment started 8/6 and continued until 10/8, correction being obtained with difficulty and relapsing almost immediately. Cephalometric records

of relapse only. 10/8 - 13/4, slight maxillary growth with moderate mandibular growth more forward than downward. 13/4 - 15/3, maxillary growth slight marked vertical mandibular growth with opening of mandibular angle, the forward component of vertical growth resulting in an increase in the reverse overjet.

2. PR. Growth Picture in Cases Showing Partial Relapse

Case No. MF66.

8/3 - 12/6, general maxillary and mandibular growth with that of the mandible relatively greater, symphyseal accretion increasing the negative angle of convexity, but the occlusion was stable. 12/6 - 13/7, negligible maxillary growth and mandibular growth marked vertically with no forward growth, accompanied by a change in the incisal relationship from an overjet to an edge to edge bite of the incisors with retroclination of the upper incisors.

Case No. MF22.

Treatment slow, with some relapses. An edge to edge bite was achieved 14/8, which was stable at 16/2. Growth picture; 10/10 - 12/2, slight growth in either jaw. 12/2 - 14/8, general growth more marked in the mandible. 14/8 - 16/2, negligible maxillary growth, slight mandibular growth.

Case No. MM33.

No cephalometric record of corrected condition at

9/11, but relapsing by 10/11. Growth record; 9/1 - 10/11, maxillary and mandibular growth with that of the mandible relatively greater. Incisor bite relapsed from overbite to edge to edge. 10/11 - 12/8, slight growth in either jaw, incisor bite stable. 12/8 - 13/8, slight maxillary growth with relatively marked mandibular growth. Incisor bite relapsed to reverse overjet but no reverse overbite therefore not regarded as complete relapse.

Case No. MM62.

Correction by 11/9 with an overjet but no overbite. Growth picture; 10/4 - 12/4, proportionate maxillary and mandibular growth. 12/4 - 14/0, slight growth in both jaws with that of the mandible greater. 14/0 - 15/4, negligible maxillary growth with marked mandibular growth and accretion at the symphysis. Incisor bite relapsed to slight reverse overjet.

Case No. PM11.

Correction with overjet and overbite 14/5. Growth record; 13/7 - 15/11, general growth of both jaws with marked vertical growth in the mandible. The incisor bite remained stable. 15/11 - 17/9, no perceptible increase in maxillary growth forwards with marked vertical and slight forward growth of the mandible. Incisor bite relapsed to edge to edge.

Relapse Cases.

3. U.S. Unsuccessful Cases.

Case No. MF55. /

Case No. MF55.

Occipito-mental traction applied for 18 months without success and referred for surgical correction. Poor prognosis initially. Growth record 8/10 - 12/8, small amount of maxillary growth with an average amount of mandibular growth.

Case No. MM22.

Considerable previous treatment to proclinate 21/12 without success. Some success achieved with fixed appliance followed by immediate relapse. Growth; 13/7 - 15/9, poor maxillary growth, good mandibular growth. 15/9 - 17/8, negligible maxillary growth with some mandibular growth.

4. O. Cases under observation only.Case No. MF 18.

Mesio-occlusion with normal overbite and congenital absence of $\overline{1/1}$. The incisal overbite changed to an edge to edge occlusion over the observation period. Growth record; 13/0 - 16/0, slight maxillary growth with positive mandibular growth, most marked vertically.

Case No. MM18.

Mesio-occlusion with normal overjet and overbite. Decreased overbite during the observation period. Growth record 10/8 - 13/4. There was horizontal and vertical growth in both jaws but more marked in the mandible.

Case No. MM29. (Plate 31).

Slight mesio-occlusion with normal overjet and overbite. Disappearance of overjet and decreased overbite increased mesio-occlusion during observation period. Growth record; 11/5 - 14/6 forward maxillary growth with marked mandibular vertical growth but little horizontal growth and symphyseal accretion.

Summary and Discussion.

The comparison of growth in the two groups made on a subjective basis shows differences of sufficient degree to be detected by this method of assessment. The principal factor appears to be the relative amounts of maxillary and mandibular growth taking place over any period. Examination of the stable cases shows a fairly consistent pattern of joint activity or relative quiescence of growth. There is a tendency for mandibular growth to be greater than maxillary in the later periods. The patterns of maxillary and mandibular growth in the "relapse" groups show a much lesser degree of synchronisation. In the early periods both jaws are growing equally. As time passes maxillary growth slows down considerably or becomes negligible in the majority of cases whilst mandibular growth persists. This results in a greater discrepancy in the relative amounts of growth in the jaws than occurs in the stable cases. As already mentioned, some increases in mandibular prognathism relative to that of the maxilla in the

later stages of growth is part of the normal developmental pattern, Bjork (1947), Lande (1952). The fault in the relapse cases may be a premature slowing of maxillary or a delayed slowing down of mandibular growth or a combination of these factors. That a deficient growth potential in the maxilla may be a greater factor in some cases is suggested by Case No. MF55, a Group B case, which showed markedly below average increments of maxillary growth from the age of 8/10 onwards, (Table 36). It will be recalled that in Group B cases deficient vertical and antero-posterior maxillary growth commonly occurs.

The site and direction of mandibular growth plays a part in determining the stability of the result. Case MF43, is a stable case, (Plate 11) but the angular changes suggest a relapse. This case shows marked mandibular growth but at the same time as gnathion has moved downward and forward, articulare has moved downward and backward to a greater extent than is seen in other cases; e.g. Case No. PF7., (Plate 27) which is a relapse case. The amount of horizontal and vertical growth of the mandible varies. In some cases it is proportionate and in others one predominates over the other. It was shown in Part I that in both Neutro-occlusion and Class III mean mandibular height increased more than horizontal length.

In Case No. PF31, (Plate 25) horizontal growth appears to be the major factor in producing the marked

relapse. Where vertical growth is predominant, the effect is to reduce the overbite rather than increase the antero-posterior discrepancy. This is well shown both in the stable and relapse cases. Decreases of overbite of varying degree associated with marked increases in the vertical component of mandibular growth were seen in Cases MF4, MM29 and PM11. In Case MF4 there was still an overbite but in the other cases the bite became an edge to edge. This is clearly again a matter of degree and is an exaggeration of a normal developmental process.

The remodelling of the symphysis termed "Symphyseal Accretion", previously mentioned, increases the negative value of the angle of convexity and was seen in a number of cases both stable and relapsed and does not appear to be a casual factor in relapse.

The time of relapse was of interest tending to occur later in boys than in girls and to be associated in several cases with the adolescent growth spurt. In girls relapse appears to set in around eleven years, Case MF39 (Plate III) is a typical example. The incisor correction remained stable for over three years, relapsing coincident with the general physical pre-menarche development, maxillary growth over this period being negligible, whilst mandibular growth was marked.

A similar picture was seen in Case MF10 which again was stable for three years, relapse occurring

between 11 and 12 years. During this period the patient's mother remarked that she had to refit her with clothes every quarter.

Where relapse occurred in boys after a period of stability the age of onset was later around 13 - 14 years, as in Cases PM5A and MM62. Not all the relapse cases were associated with relapse at the adolescent period following a period of stability. Several cases relapsed immediately such as Cases No. MM11, MM43, and PM8. In these cases there was nothing to indicate that the basal malrelationship was too great at the start of treatment to permit of a stable result. In those cases where records covering the period were available such as MM11, a marked worsening occurred during the period of adolescence.

The general picture of growth in both the stable and relapse cases suggests a relationship with adolescent development. The periods of most active growth in both jaws over the period observed (approx. 8 - 17 years) tended to occur earlier and die out earlier in girls than in boys. Complete serial studies are not available and accurate figures cannot be given but the few cases observed in the older age groups suggest that by 15 years or earlier the adolescent spurt as regards jaw growth had finished in the girls, (Plate 24), maxillary growth exhausting itself earlier than mandibular, where-as in the

boys, maxillary growth is tailing off by 15 - 16 years and mandibular growth is slowing by 16 - 17 years. (Plates 22, 28) It must be stressed that these are only observations on a few cases and no generalisations are being made. It is suggested that individual studies of growth over this period in normal and abnormal occlusions would be of value. Tanner (1955) comments on the relative lack of orthodontic studies covering this aspect of facial growth. He states that there is little doubt that an adolescent spurt occurs in most facial measurements and that it is greatest in the mandible, the maxilla accelerating slightly. Figures given by Tanner for the average onset and duration of the spurt in height at adolescence are $10\frac{1}{2}$ - 16 years in boys with a peak at about 14 years and $9\frac{1}{2}$ - $14\frac{1}{2}$ years in girls with a peak at 12 years. The observations made on maxillary and mandibular growth fit approximately into these periods.

A further matter for investigation in relation to facial growth is the relative influence of the gonadotrophic hormones upon cartilaginous as opposed to appositional and sutural growth of bone, the former being the principal factor in mandibular and the latter in maxillary growth. The relatively greater mandibular than maxillary growth during the adolescent spurt is presumably a matter of hormonal control and appears to be the critical factor in

determining stability or relapse. Confirmatory evidence is seen in the marked response to treatment often seen in disto-occlusion cases during this period. Here the relatively greater mandibular growth is a major factor in successful treatment.

Knowledge of the imminence of the adolescent spurt would be of advantage in the timing of orthodontic treatment generally and it would be of interest to know whether there is any clinical test by which the commencement of the pubertal hormonal secretion can be detected.

Conclusions. Comparison of "Relapsed" and "Stable" Cases.

1. The principal factor in the relapse or unsuccessful treatment of mesio-occlusion was an unfavourable maxillary-mandibular growth pattern resulting in an increasing degree of malrelationship with age.
2. A marked worsening occurred during the adolescent growth spurt causing relapse in cases where a stable result had been obtained and making unsuccessful cases untreatable by orthodontic means.
3. No diagnostic criteria in terms of the cephalometric analysis could be established to differentiate the stable group from the relapse group before treatment.
4. The principal factor in ensuring stability of the treated result is a favourable growth pattern.
5. No evidence was found in the study of the

growth of the jaws in the treated cases to suggest that orthodontic appliance treatment had any effect on the basic growth pattern.

6. The type of appliance used in treatment was not a factor in the stability or relapse of the treated case.

Summary and Conclusions. Part II.

A clinical and roentgenographic cephalometric analysis has been made of 139 cases of mesio-occlusion, (Angle's Class III malocclusion). Nine cases were judged untreatable by Orthodontic means. Serial observations have been made of the changes in angular relationships following Orthodontic treatment in the remaining 130 which were grouped as follows, based on the dentitional stage at the first examination:-

Deciduous dentition	14
Mixed dentition	96
Permanent dentition	20
Total	<u>130</u>

The purpose of the analysis was to determine:-

1. What are the changes that follow Orthodontic treatment and to what extent are the changes the result of treatment or of growth?
2. What are the factors associated with the relapse of a corrected malocclusion?

The investigations carried out to determine these questions were as follows:- The material was divided into three sections -

I Those cases whose treatment was started in the deciduous dentition - deciduous dentition cases.

II Those cases whose treatment was started in

the mixed or permanent dentitions - mixed and permanent dentition cases.

III Those cases which relapsed or were unsuccessfully treated.

I. Deciduous dentition cases (14) were investigated chiefly for aspects of treatment and growth peculiar to their age range. These aspects and others investigated were:-

- a. The effect upon the subsequent occlusion of the permanent incisors of the correction of a reverse overjet and overbite in the deciduous incisors.
- b. The effects of backward traction upon mandibular growth.
- c. Factors governing the development of the permanent incisor occlusion.
- d. The growth changes in the anterior cranial base and in the mandible.

II. Mixed and Permanent dentition cases (97)

The cases were grouped according to the type of orthodontic appliance employed and the dentitional stage. The changes were recorded in those angles of the cranio-facial diagrams which were thought to be primarily or secondarily affected by the various forms of appliance treatment or by growth changes. The amount of growth was assessed subjectively by superimposition of the serial tracings.

III Relapsed or unsuccessful cases (19).

For the investigation into the causes of relapse

or failure in treatment, a detailed comparison was made between the 19 "relapse" cases and 10 successful cases in which the corrected occlusion had been stable for 4-5 years.

A general comparison was made of growth changes between the "relapse" and successful cases. Included in the letter in addition to the ten mentioned above, were a further six cases showing long term stability.

Summary of the findings of the investigations made and of the conclusions based on them.

I. Deciduous Dentition Cases.

1. The correction of a reverse overjet of the deciduous incisors does not influence the occlusion of the permanent incisors.

2. Backward traction on the mandible had no discernible effect upon the direction and amount of mandibular growth in three cases and this form of treatment is of doubtful value.

3. The primary factor governing the occlusal relationships established by the permanent incisors on eruption is the maxillary-mandibular basal bone relationship and not the pre-eruptive inclinations of the incisors.

4. The cranial base angle is constant after birth and growth of the anterior cranial base proper ceases approximately between the ages of 7-8 years.

5. The mandibular angle shows a marked tendency

to decrease between 4-10 years. Marked remodelling of the alveolar profile at the symphysis frequently occurs with the change from the deciduous to the permanent incisors.

II. Mixed and permanent dentition cases whose treatment was successful:-

A. The principal angular changes found immediately after appliance treatment in 97 cases were as follows:-

1. An increased proclination of the upper incisors and a retroclination of the lower incisors. The spontaneous retroclination of the lower incisors following proclination of the upper incisor only by appliance treatment, was a marked feature in the mixed dentition cases.

2. A reduction in the angle of the occlusal plane to the cranial base.

3. A positive increase in the A/B difference (\angle SNA- \angle SNB) and in the angle of convexity (Downs!).

4. An increase in the angle of the Y Axis and in the angle of the mandibular plane to the cranial base.

5. The angle of the maxillary plane to the cranial base was relatively unchanged in the majority of cases.

6. The A/B difference, and the angle of convexity, the Y Axis and mandibular plane angle, showed the greatest changes in cases with evidence of overclosure or forward displacement of the mandible

in occlusion before treatment and the least or no change in cases with a normal path of closure before treatment. The changes in the angles of the incisors and in the occlusal plane angle are directly due to the appliance treatment. The remaining changes follow from the alteration in mandibular position consequent upon the correction of the incisor occlusion.

B. Follow up studies of the angular changes in 57 of the 97 successful cases.

These naturally showed a relative stability of the changes in incisal axial inclination with only a slight tendency to relapse. There was a relatively greater tendency for the other angles, especially the angle of the Y axis and the angle of convexity, to return to their original values. Since these two angles reflect the direction of maxillary and mandibular anterior growth, this is evidence that the appliance treatment has not altered the basic pattern of growth and that where this is unfavourable it will nullify any improvement in mandibular position effected by the occlusal readjustment.

C. A comparison of the effects of differing forms of appliance treatment and of the results of the same appliance used in different Class III patterns.

There was no difference in the general effect produced by the different forms of appliance nor was there any difference in the response of the three main

Class III patterns to the same method of treatment.

D. Growth changes.

The overall picture of growth in the serial studies showed downward and forward movement of the maxilla and mandible in relation to the cranial base and agrees with the current concepts of normal facial growth.

The individual growth of the maxilla and of the mandible varied markedly in amount and direction in different individuals. The amount and direction of facial growth was not influenced by appliance treatment.

The mandibular angle increased in some cases and decreased in others in contrast to the consistent tendency to decrease in the deciduous dentition cases.

Further findings and conclusions on growth changes are given in the following section.

III. Comparison of Stable and Relapsed Cases.

The stable and relapsed cases were under observation for an average period of 4-5 years. The findings and conclusions reached about the factors making for stability or relapse after treatment are:-

1. The principal factor in the relapse or unsuccessful treatment of mesio-occlusion is a disproportionate amount of mandibular growth relative to maxillary growth producing an increase in the degree of malrelationship between the jaws and evidenced by a marked negative increase in the angle of convexity.

2. This unfavourable growth trend may be a continuous factor militating against successful treat-

-ment or may not become manifest until the onset of the adolescent growth spurt and may then cause the relapse of cases in which the corrected occlusion has been stable for three or more years.

3. A corollary of the above finding is that no case of corrected mesio-occlusion can be regarded as satisfactorily completed until after adolescence.

4. No diagnostic criteria in terms of either the linear or angular cephalometric analysis or the "differential analysis" of Class III facial patterns (Groups A, B and C) could be established to differentiate the stable from the relapse cases, or the initially treatable from the untreatable. Clinical judgement must therefore continue to be the final arbiter.

5. The principal factor in the stability of the stable case is a proportionate forward growth of maxilla and mandible or in other words a favourable growth pattern.

6. The analysis of a case before treatment gives no indication of future growth trends.

7. The type of appliance treatment had no bearing on stability or relapse.

Final Conclusions Part II.

1. The changes in the cranio-facial pattern in mesio-occlusion found after appliance treatment are in general the results of growth and development and are not related to the appliance treatment except for changes in incisal inclination and alterations in the mandibular position in occlusion consequent upon the correction of the incisal relationships.

2. The amount and direction of jaw growth in mesio-occlusion is not influenced by appliance treatment.

3. The cause of the relapse occurring in corrected cases of mesio-occlusion is a failure of maxillary forward growth to keep pace with mandibular forward growth. (This occurs in approximately one case in six.)

4. This relative failure of maxillary growth tends to occur during the adolescent growth spurt.

REFERENCES:

* Signifies original reference not examined.

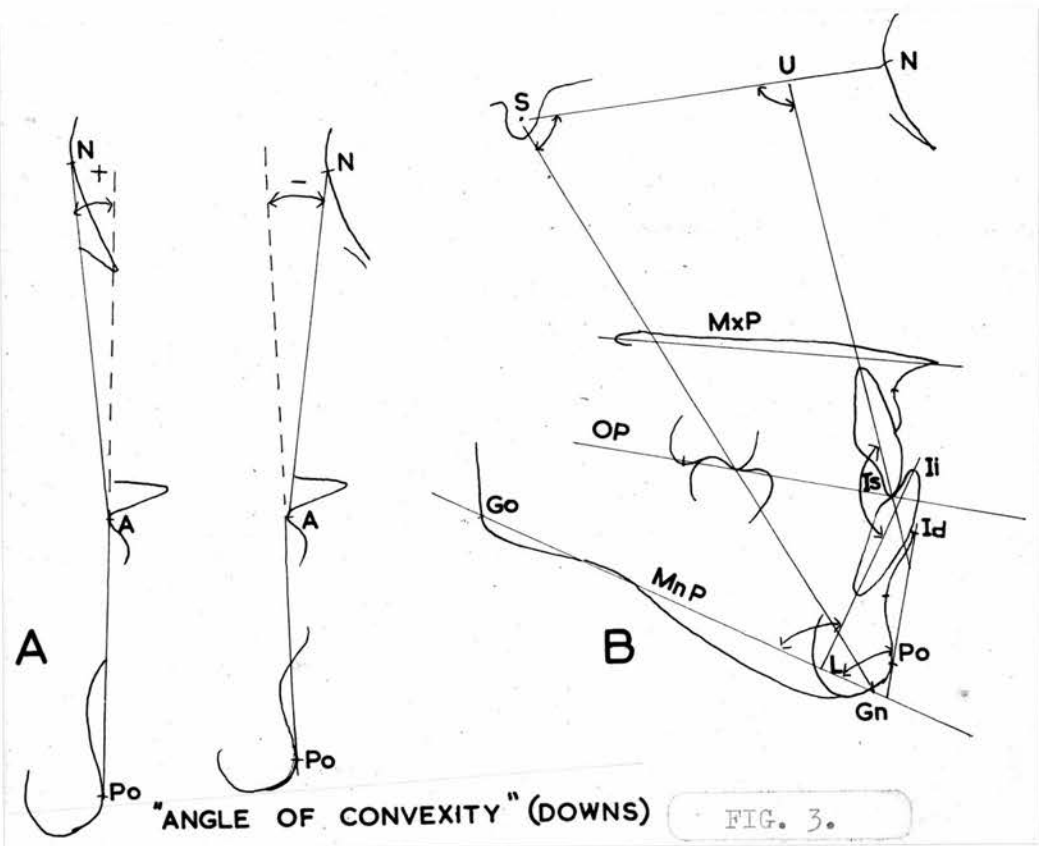
- ADAMS, J.W. (1940). Correction of error in cephalometric roentegenograms. Angle Orthodont 10: 3-13.
- _____ (1948) Cephalometric studies in the form of the human mandible. Angle Orthodont 18:8.
- ANGLE, E.H. (1899) Classification of Malocclusion. Dent. Cos. 41: 248-264.
- BALLARD, C.F. (1948) Some bases for aetiology and diagnosis in orthodontics Dent. Rec. 68: 134-45.
- _____ (1951) Recent work in North America as it effects diagnosis and treatment. Dent. Rec. 71: 85-97.
- BARCROFT, J. (1946) Researches in Pre-natal life. Blackwell Scientific Pub. Oxford.
- BJORK, A. (1947) The face in Profile. Svensk Tandlak - Tidskaf. 40: 513.
- _____ (1951) The significance of growth changes in the facial pattern relationship to changes in occlusion. Dent. Rec. 51: 197-208.
- _____ (1955) Cranial base development Amer. J. Orthodont 41: 198-225.
- _____ (1958) Käkarnas tillvaxt och utveckling i relation till kraniet i Dess Helket. Nord Klinisk Odont. Band 2.
- BJORK, A and PALLING, M. (1954) Adolescent age changes in saggital jaw relationship. Alveolar prognathy and mesial inclination. Acta Odont. Scand 12: 201-32.
- BRACCESI, M.A. and LUCCHESI, P. (1958) Skeletal and Dental changes in 30 treated Class III Malocclusion cases studies by cephalometric analysis. Trans. Europ. Orthodont Soc. 211-214.
- BRASH, J.C. (1929) The aetiology of irregularity and malocclusion of the teeth. (2nd ed. with Scott, J.H. and McKeag, H.T.A.) (1956) Dental Board London.
- BREITNER, C. (1940) The influence of moving deciduous teeth upon their permanent successor. Amer. J. Orthodont and Oral Surg. 26: 1152-1177.
- BROADBENT, B.H. (1931) A new X-ray technique and its application to orthodontia Angle Orthodont 1: 45-66.
- _____ (1937) Bolton Standards technique in Orthodontic practice. Angle Orthodont. 7: 208-33.
- BRODIE, A.G. (1941) On the growth pattern of the human head from the third month to the eighth year of life Amer. J. Anat. 68: 209-62.
- BRODIE, A.G. DOWNS, W.B. GOLDSTEIN, A. AND MYER, E. (1938). Cephalometric appraisal of Orthodontic results. Angle Orthodont 8: 261-351.
- COBEN, S.E. (1955) Integration of Facial Skeletal variants Amer. J. Orthodont. 41: 407-434.

- DE, COSTER, L. (1927) Les Deviations sagittales Etude Cephalometrique L'Orthodontic Francaise 5: 93-125.
- _____ (1929) Une Methode d'Analyse des malformations Maxillo-facial. L'Orthodontic Francaise 7: 117-154.
- _____ (1939) The network method of orthodontic diagnosis Angle Orthodont 9: 3-14.
- _____ (1951) Une nouvelle ligne de reference pour l'analyse des telerradiographies saggittales en orthodontie. Rev. de Stomatolog. 11: 937-53.
- DICK, M.F. (1954) A study of the variability of Cephalometric landmarks M.S.D. Thesis Northwestern University.
- DIXON, D.A. (1959) Personal Communication.
- DONOVAN, R. (1953) A radiograph cephalometric consideration of facial growth during orthodontic treatment. Amer. J. Orthodont. 39: 340-357.
- DOWNES, W.B. (1948) Variations in Facial relationships. Amer. J. Orthodont. 34: 812-40.
- ELSASSER, W.A. and WYLIE, W.L. (1948). The cranio-facial morphology of mandibular retrusion. Amer. J. Phys. Anthropol., N.S. 6, 461.
- ETTER, L. (1955) Atlas of Roentgen Anatomy of the head. Springfield U.S.A.
- FORD, E.H.R. (1958) Growth of the human cranial base. Amer. J. Orthodont 44: 498-506.
- GOULD, D.G. (1960) A Class III case treated with simple apparatus. Dent. Pract. 10: (Trans. B.S.S.O.) 66-69.
- *GRIEVE, H.C. (1921) Grundlagen der Odontorthopadischer Kiefermessung. Dent. Zahnk. 49.
- GUGNY, M.C. (1959) Discussion de resultats de traitements Class III d'Angles. Rev. Franc. d'Odont. Stomatolog. 6: 551-563.
- HALLET, G.E.M. (1959) Inherent errors in cephalometric films and their reduction. Dent. Pract. 9: 163-171 (Trans. B.S.S.O.).
- HATTON, M.E. and GRAINGER, R.M. (1958). Reliability of measurements from cephalograms at the Burlington Orthodontic research centre. J. Dent. Rec. 37: 853-859.
- HAUPTMEYER, F. (1913). "Uber die anatomischen Veranderungen des Unterkeifer bei einigen Stellun granomalien Der Zahne" Dtsch. Mschr. Zahnheilk 31: 153-170.
- HAUSSER, E. (1956). "The relation of the facial pattern to the cranial base." The Teleroentgenography Acta. 1952-53. Pub. Barth. Leipzig (1956).
- HELLMAN, M. (1927a). "Face and occlusion of the teeth in man." Int. J. Orthodont. 13: 921-943.
- _____ (1927b). Changes in the human face brought about by development. Int. J. Orthodont 475-515.
- _____ (1931). "Morphology of the face, jaws and dentition in Class III malocclusion." J. Amer. Dent. Ass. 18: 2150-2173.
- _____ (1939). "Facial features and Orthodontic implications" Amer. J. Orthodont. 25: 927-951.

- HOFFRATH, H. (1931). Die Bedeutung der Roentgenfern und Abstands aufnahme für die Diagnostik der Kieferanomalien. Fortsch. der Ortho 1: 232.
- HRDLICKA, A. (1920). Anthropometry p.p. 92-93 Wistar Institute, Philadelphia.
- IZARD, G. (1927). The gonio-mandibular angle in Dento-facial Orthopedics. Int. J. Orthodont. 13: 578-871.
- JEAN, R. (1957). Étude céphalométrique de la classe squelettique III Orthodont franc. 28: 369-389.
- JENSEN, E. and PALLING, M. (1954) The gonial angle. Amer. J. Orthodont. 40: 120-133.
- KANTOROWICZ, A. (1926). Self correction of Orthodontic anomalies. First Int. Orthodont Congress.
- KEEN, J.A. (1945). A study of the angle of the mandible. J. Dent. Rec. 24: 77-91.
- _____ (1950) A study of differences between male and female skulls. Amer. J. Physic. Anthropol 8: 65-79.
- KEITH, A. and CAMPION, G.G. (1922). A contribution to the mechanism of growth of the human face. Int. J. Orthodont 8: 607-633
- KORKHAUS, G. and NEUMANN, D. (1957). Über die Beteiligung von Oberkiefer und Unterkiefer bei der Progenie. Forts. der Keifer orthop. Band 18: 142-158.
- KORKHAUS, G. (1957a) Diagnosis in dento maxillo-facial Orthopedics. Int. Dent. J. 7: 155-188.
- _____ (1957b). Disturbances in the development of the upper jaw and middle face. Amer. J. Orthodont. 84: 848-881.
- _____ (1934). Self correction of malocclusion. J. Dent. Research 14: 221.
- KOSKI, K. (1953). Roentgenographic - Cephalometric methods used in diagnosis of developmental disturbances of the dento facial complex. Odontologisk Tidskrift 59: de arg N:0 1-2, 11-33.
- KROGMAN, W.M. and SASSOUNI, V. (1957). Syllabus in Roentgenographic Cephalometry Philadelphia, Centre for Research Child growth.
- LANDE, M.J. (1952). Growth behaviour of the human bony profile as revealed by serial cephalometric Roentgenology. Angle Orthodont. 22: 78-90.
- MAJ, G. LUZI, C. and LUCCHESI, P. (1957). A new method of Analysis of the Development of the jaws and of position of the teeth. Trans. Europ. Orthodont. Soc. 135-149.
- _____ (1958). Skeletal and Dental behaviour in Class II Div. I and Class III cases. Trans. Europ. Orthodont. Soc. 37-93.
- MARRONEAUD, P.L. (1956). Cephalogenese et "ligne de reference" Cahiers Odonto - Stomatolog 6: 17-58.
- MEREDITH, H.V. (1957). Change in the profile of the osseous chin during childhood. Amer. J. Physic. Anthropol. 15: 247-52.
- MOORE, A.W. (1959). Observation on facial growth and its clinical significance Amer. J. Orthodont. 45: 399-423
- MOSS, M.L. and GREENBERG, S.N. (1955). Post natal growth of Human Skull base Angle Orthodont. 25: 77-84.

- MOYERS, R.E. HARVOLDE, E. JENKINS, H. SHULTIS K. AND CROUCH, J. (1954). Intra oral factors affecting case assessment. Amer. J. Orthodont. 40: 341-349.
- MULLER, G. (1959). Über die wachstumsbedingten Lageveränderungen von Sella Turcica Nasion und Porion in der normalis lateralis nach. Fernrontgenaufnahmen. Fors. der Kieferorthopädie 20: 204-213.
- MCCALLIN, S.G. (1955). Angle's Class III malocclusion. Trans. B.S.S.O. 91-104.
- MCCORMACK, W.J. (1949). A Cephalometric Roentgenographic comparison of the upper face and associated structures in individuals with Class I Division 1 and Class III malocclusions. Thesis Northwestern Univ.
- NOYES, H.J. RUSHING, C.H. and SIMS, H.A. (1943). The angle of axial inclination of human central incisor teeth. Angle Orthodont 13: 60-61.
- PARKER, A.D. (1960). A Class III case with over closure. Dent. Pract. 10: 59-65. Trans. B.S.S.O.
- * PFAFF, C.L. (1923). Rassenkranziologische Untersuchungen über die Stellung des oberen M.1 im Kiefer gerüst. Dtsch. Zahnk. 61.
- RITCHIE, J.C. (1960). The orthodontic treatment of a set of Uniovular Quadruplets. Dent. Pract. 10: 73-82. (Trans. B.S.S.O.)
- RUSHTON, W. (1911). Mouth Breathing and facial contour with a suggested Classification. Trans. Brit. Soc. Study. Orthodont. 4-6.
- SALTER, R.B. and FIELD, P. (1960). The effects of Continuous Compression on living articular cartilage. J. Bone Joint Surg. 42.A: 31-49.
- SANBORN, R.T. (1955). Differences between the facial skeletal patterns of Class III Malocclusion. Angle Orthodont. 25: 208-222.
- SCHOENWETTER, R.F. (1948). The relationship of the upper and lower first permanent molars to the face in Class III malocclusion. Angle Orthodont. 18: 16-19.
- SCOTT, J.H. (1954). The growth of the human face, Proc. Roy. Soc. Med. 47 91-100.
- _____ (1956). Growth at facial sutures. Amer. J. Orthodont. 42: 381-387.
- _____ (1958). The cranial base, Amer. J. Physic. Anthropol. 16 NS: 319-348.
- SICHER, H. (1954). Positions and movements of the Mandible. J. Amer. Dent. Ass. 48: 620-625.
- SICHER, H. and KRASA, F. (1920). Anatomische Untersuchung an Schäl den mit Stellungs anomalien der Zahne. Eister teil Osterreichische. Ztshr. f. Stomat 18.
- _____ (1922). Zweiter teil ibid. 20.
- SNEDECOR, G.W. (1956). Statistical Methods. Page 85 5th Edit. Iowa State College Press.
- STAFF, W.S. (1948). A cephalometric and Roentgenographic appraisal of the facial pattern in Class III malocclusion. Angle Orthodont. 18: 20-33.

- STEINER, C. (1953). Cephalometrics for you and me. Amer. J. Orthodont. 39: 729-55.
- STRAMRUD, L. (1959). External and Internal Cranial base. Acta. Odont. Scand. 17: 239-266.
- TANNER, J.M. (1955). Growth at adolescence. Blackwell, Oxford
- THOMPSON, D'ARCY, W. (1917). On growth and form (new edition 1942). Cambridge.
- TULLEY, W.J. (1957). Observation of the Path of eruption of the incisors. Trans. Europ. Orthodont. Soc. 279-289.
- WERNER, H. (1955). Determination of the Cephalometric orientation of the jaws. Acta Odont. Scand. 13: 205-216
- WEINBERGER, B.W. (1926). Orthodontics An Historical review of its origin and evolution. Vol. 1. P. 284. C.V. Mosby St. Louis.
- YOUNG, M. JOHNSTONE, E. SMITH, K.C. and STILL, M. (1937). Investigation into the nature and characteristic features of post-normal occlusion. Med. Res. Council. Special Report No. 225.



"ANGLE OF CONVEXITY" (DOWNS) FIG. 3.

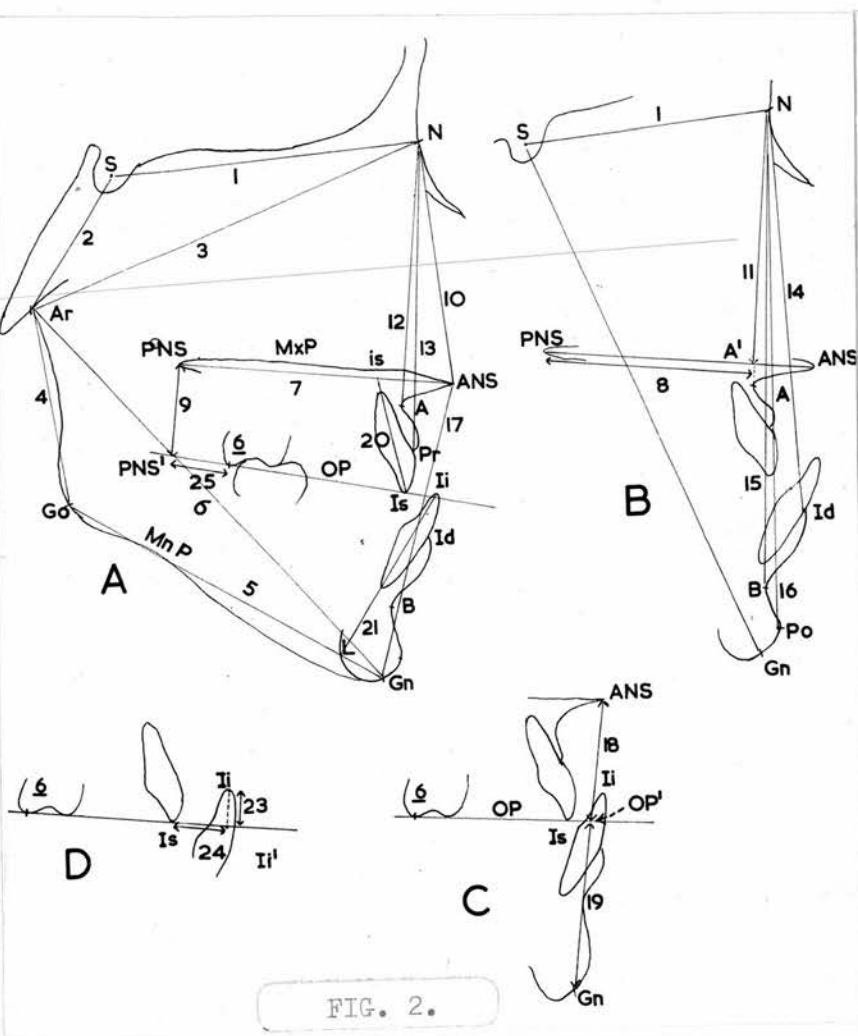


FIG. 2.

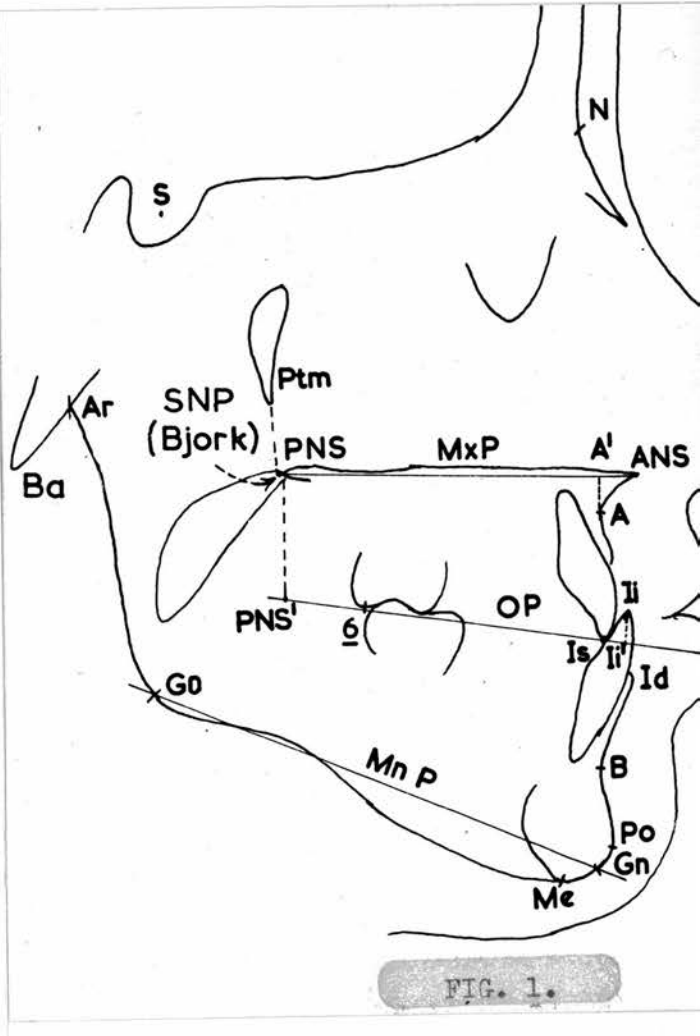


FIG. 1.