EXTRACTIONS IN ORTHODONTIC THERAPY.

GROWTH AND DEVELOPMENT.

CLASS III MALOCCLUSION.

R. H. McCROSSIN. B. D. S.

1958

EXTRACTIONS IN ORTHODONTIC THERAPY.

From the earliest days of Orthodontics, teeth were extracted as a routine procedure, permitting teeth to shift and migrate. Weinberger [1] states that, since 1880, there has been continual controversy about the value of extractions in Orthodontic therapy. Different authors have recommended that cuspids, bicuspids, molars, even incisors, should be extracted. In 1887 Isaac Davenport strenuously opposed extractions.

As late as 1892, Angle in "The Angle System of Regulation of the Teeth" recommended extraction, and described the closing of the spaces created after extracting four bicuspids. In 1893 Case [2] began the so-called "premolar extraction wave and he recommended extractions for what he called "bimaxillary protrusions" throughout his career. However Angle, by the turn of the century, was uncompromisingly opposing extractions and indoctrinated his students. He brought forth his dictum of the full complement of teeth with normal occlusion of the teeth as the ultimate goal of treatment. His influence was so strong that, for many years, practically all the leading orthodontists opposed extractions, and Case had little support.

Hellman in 1921 in the Dental Cosmos demonstrated that what Angle called the normal was actually an imaginery "Ideal" occlusion.

White [4] states that Angle and Case represent the period which first evidenced a scientific approach to Orthodontics.

Fairbanks [5] states that the dictum of the integrity of the dental units dominated the thinking and action of the Dental profession, and feels that no one factor was responsible for so many failures among honest and conscientious Orthodontists. The Huning case, reported by Angle, [3] influenced him greatly. He treated this child without extractions, and at the end of active treatment, the dentures were definitely protrusive. However, when Angle saw her again some years later, due to favourable growth, her appearance had greatly improved.

Angle's contention that bone could be made to grow [6] was based on Wolff's law which referred to changes in form being associated with changes in function. However Brodie [7] states that Angle incorrectly interpreted the Law by inferring that <u>increase in size resulted from increase in function</u>.

Andrew Francis Jackson [8] in an interesting assessment of the problem, said that he feels that, if Angle were still alive, he would quite probably have changed his mind again as new scientific facts were presented to the profession. However his disciples were so strongly impressed by him that they uncompromisingly opposed extractions. To quote Jackson [8] "As a result of thousands of years of intermingling of races, we see every combination of the volume of tooth substance and bony development that can occur. Consequently in some cases, extractions are necessary".

In another article [9] Jackson presents cases showing tremendous variations in the size of the teeth even in children of the same family, and he asks how one could possibly contemplate treatment of some of these cases without extractions.

During the first 35 years of the twentieth century, there were few orthodontists recommending extractions. Case in 1912, Sundstrom in 1925, George Grieve in 1932 and Stanton recommended extractions in cases with inadequate bony support, but received little or no support from orthodontists.

Strang [10] on page 603 of his text book states that the forward displacement of buccal segments in relation to cranial anatomy (i.e. bi-maxillary protrusion cases) was not mentioned in the literature until 1924 when Strang published an article in the Dental Cosmos. Shortly afterwards Dr Grieve advocated extractions in these cases. Previously they were treated by general denture expansion, and these cases almost invariably relapsed. Dr Angle [3] shows a photograph of one of his treated cases onP.544 of his text book, and this illustrates how extremely some of these cases were over-expanded.

Two events occurred,however, which promoted a general change in thinking. One was the arrival of the Cephalometer,[11] and the other was the presentation of the Tweed Philosophy by Dr C.H.Tweed, supported by his mass of clinical evidence.[12.] at this stage. Tweed stressed the importance of the Lower Incisor - Mandibular Plane Angle, stating that the normal range was from $85^{\circ} - 95^{\circ}$.

In 1943 Margolis [13] published findings which tended to verify this.

In 1945 Tweed [14] described his "Philosophy". He stated that in non-orthodontic normal occlusion we see

1. Angular Inclination of lower incisors between $85^{\circ} - 95^{\circ}$,
2. Mandibular Alveolar process thin,

For successful treatment of Class I , Class II , & Bimaxillary Protrusion cases, Tweed stated that the Mandibular incisors must be positioned over "basal bone" . He endeavoured to place them at "MINUS 5°" to safeguard against relapse, as function will drive the denture forward until it finds its functional balance point, somewhere within the range -5° to $+5^{\circ}$. Tweed states in this article that, previously, the normal procedure was to accept the position of the mandibular incisors a s correct, then to occlude the maxillary teeth to them, regardless of the relation of the mandibular teeth to their bony bases.

During his first years as an orthodontist, Tweed treated his cases without extracting. However in many cases he found that the jaw relation was transformed from Class I or Class II (Angle) before treatment, to Bimaxillary protrusions after treatment. Thus these cases were failures because

(a) Poorer aesthetics after treatment or

(b) Relapse.

Both of these were due to expansion of the arches in labial and/or buccal ~~sequences~~ segments, and frequently led to recession of gingival tissues. Herzberg [15] historically traces Tweed's procedures from this stage. To combat these failures at first Tweed began to upright mandibular incisors over mandibular base, at the expense of excessive expansion in cuspid and buccal segment areas. He soon found that he could not maintain the expansion, and it became necessary to extract in order to upright mandibular incisors without much expansion. He first advocated this extraction in 1936,[16] and it was not favourably received. However research into growth and development has confirmed the fact that there is frequently discrepancy between tooth material and base bone. Strang[10] states that he practiced orthodontics for 36 years without extraction, but he changed and commenced extractions in cases of pronounced forward positioning of dental units on basal bones exhibiting definite evidence of retarded growth, in order to

1. Obtain a stable result,
2. Avoid destruction of osseous tooth-supporting tissues,
3. Effect harmony of facial lines.

Strang feels that this is particularly true if patients exhibit hypertonic facial musculature, or perverted muscular habits.

Tweed's treatment proceeds in 3 steps (1) Anchorage prep. in mandib denture, (2) En Masse movement to correct jaw relationships, (3) Detailed tooth positioning If there is insufficient base bone to accommodate all the tooth structure, then Tweed extracts.

In previously-treated cases, where bi-maxillary protrusions were produced, collapse in the incisor region usually occurred, as nature endeavoured to correct the muscular imbalance by positioning the denture back within the range of mechanical functional balance.

Tweed retreated many of these failure cases by four bicuspid extractions, and they proved to be stable. He claims that in discrepancy cases, treated at the right time, in 80% of cases the 3rd. molars come into normal occlusion. Tweed emphasised that extraction does not necessarily make the treatment easier. He stated that space closure requires the ultimate in Orthodontic management.

Dinham [17] discussed the mandibular Incisor Axial Inclination, and quoted Speidel, Stoner, & Morris, [18] who found that in 69.3% of all cases studied, the mandibular incisor axial inclination fell within the range of -5° to $+5^{\circ}$ in relation to a line at right angles to the mandibular plane.

Dinham believes that the mandibular incisor-axial angle is a fundamental in the consideration of the extraction problem in Orthodontia. To correctly position the incisors over basal bone, extractions are necessary in a percentage of cases and make it possible to attain certain objectives, listed by Tweed [12] as

(1) Stability of End Result,

(2) Healthy Investing Tissues,

(3) An efficient Dental Apparatus,

(4) The best of Facial Aesthetics.

Brodie [19] has stated that some people have thought that the report by Downs, Goldstein, Meyer, a nd Brodie [20] in 1938 caused the resurgence of extractions at that time. However, Brodie says that Tweed advocated the procedure previously (1936) but that this report "certainly added fuel to the fire".

In 1938 Downs, Meyer, Goldstein, and Brodie appraised the results of 6½ years of work at University of Illinois.

Angle believed that normal occlusion led to normal development : normal occlusion if established and held whilst vigorous function is promoted, then the result would be the best form and balance for that face.

However the report summarised was

(1) Teeth can be moved bodily by orthodontia, but tipping is the usual movement,

(2) Elastics alter the angle between Occlusal and Bolton planes, Class II open the angle, Class III close the angle,

(3) This angle tends to return after treatment.

(4) In a number of cases of all classes, part of the result obtained is due to a change in the position of the mandible,

sometimes a horizontal antero-posterior shifting but

usually a downward and backward rotation of mandible (opening of bite)

(5) Axial inclination of teeth, disturbed by orthodontic treatment, tend to return after treatment.

(6) Actual bone changes accompanying the treatment seem to be restricted to alveolar proces. This structure has great ability to adapt itself to changes in position of teeth.

(7) Changes subsequent to treatment are limited to shiftings in the occlusal plane and to changes in the axial inclination of teeth in adult cases. In growing children there are, in addition, the typical changes that are expected in growth.

(8) There seems a definite correlation between success of treatment, and growth. The adult cases, though clinically successful as far as maintenance of occlusal relations is concerned, are not so markedly improved aesthetically.

In 1946 Tweed[21] brought the Frankfort Mandibular Plane Angle into prominence for Diagnosis. Tweed held that the size of the angle governed the quality of facial aesthetics that can be obtained. Tweed felt that if the Angle is

	$20^\circ - 30^\circ$	=	excellent to good aesthetics can be obtained
if	$30^\circ - 35^\circ$	-	good aesthetics can be obtained
if	35° -	-	then only fair aesthetics can be obtained
if	35° +	-	poor aesthetics only

However Buchin [22] (1957) could find no significant correlation between the F.M.P. Angle and the prognosis for improvement in facial aesthetics.

Tweed now concentrates on the Frankfort - Mandibular Incisor Angle. In 1954 in an article in the Angle Orthodontist [23] he stated that most of the work done in cephalometrics has been to study growth and development, and wondered how cephalo -metrics can be used to benefit routine diagnosis and treatment planning.

He selected four treated cases in which he thought that the aesthetics were pleasing: then on the lateral head plate he drew a triangle consisting of

(1) The Frankfort Plane

(2) The Mandibular Plane

(3) A line through the axis of the mandibular incisor extended to intersect the Frankfort plane.

He measured the F.M.I.A. of these four cases, and found angles of 65°, 66°, 64.5°, 65°.

Tweed had long considered that the normal variations are

F.M.A.varies from 20° - 30° with an arbitrary norm of 25°

I.M.P.A. (Inclination of Mandib. Invisor) varies from 85°-95° with 90° norm.

Therefore F.M.I.A. norm would be 65°.

Work done by Downs, Brodie, et al at University of Illinois give the norm F.M.A. at 21.9°, I.M.P.A. norm at 91.4°, F.M.I.A. norm at 66.7°.

Tweed then picked out 45 non-orthodontic people, whose facial aesthetics appealed to him as good. He took photographs and lateral headplates of these subjects and found the following averages

F.M.A.	24.9°
I.M.P.A.	86.6°
F.M.I.A.	68.6°

Tweed this concluded " That my minimum requirements of an F.M.I.A. of 65° is not harsh, and that the dividing point between extraction and non-extraction, an F.M.I.A. of 62°, is quite liberal.

Thus Tweed's method of treatment <u>now</u> is

Take a lateral headplate and draw in the triangle (Frankfort, Mandibular Plane, Mandibular Incisor Axis) in white ink. A dotted line is then drawn from the apex of the mandibular incisor to intersect Frankfort at 65°. The distance between the solid line (existing inclination of mandibular incisors) and the dotted line is the distance which the mandibular incisors must be tipped lingually. For Class II cases, 70° is aimed at, at the conclusion of anchorage preparation, to allow for a 5° forward displacement during Class II traction.

Tweed presents 37 consecutive cases treated by this formula. Seven were non-extraction cases, and he feels that this would be a slightly lower % of extraction cases than by his previous method.

Tweed concludes that -

If the case is not a discrepancy case, and the mandibular incisors are hot irregular, and the facial aesthetics are fair then, even if F.M.I.A. is 57° or 58° he would not advocate exn. of 4 bis to attain an F.M.I.A. of 65°.

However, if the mandibular denture is unstable, and facial balance poor, Tweed would remove four bicuspids and strive for an F.M.I.A. of 65° or greater.

Tweed's method or "philosophy" is widely followed in U.S.A. and many articles have been written by other men describing the treatment of various cases, using this philosophy. However, there have been several articles criticising his methods.

Schwartz[24] compares Tweed's widely-accepted conception of the normal to other concepts which exerted great influence over orthodontic thinking in previous years - notably Angle's assertion of the constancy of maxillary first permanent molar position, and Simon's Law of the canine.

Downs[25] selected 25 individuals, whose occlusion he judged to be normal, and analysed them cephalometrically. Schwartz states that Downs did not intend that the standards derived from his analysis should be widely used as a method of cephalometric diagnosis, as has occurred.

Brodie, Wylie, Bercu, Fischer, Sved, Graber and others have all written against the "norm" concept and feel that each patient has his own individual morpho-genetic pattern, which is stable and cannot be ignored. Cases examined 10 to 30 years out of retention have shown a strong tendency to return to the original pattern of malocclusion. The malocclusion represents a state of equilibrium between the forces acting on the denture

(a) Pressure of tongue and lips

(b) Action of inclined planes of teeth

(c) Forces of growth and development.

Schwartz feels there is only a small range of movement within which stability can be maintained. Marked changes can be achieved by

(1) Correction of Mechanical displacement

(2) Growth during treatment period

but any change in the basic morphogenetic pattern holds only so long as retainers are worn.

Brodie[26] states that the individual cannot be judged against a statistical yardstick derived from a group. His opinion is that it is absurd to attempt a diagnosis on the basis of a single angle, or even a combination of angles.

Wylie[27] studied Tweed's [23] 1954 article and criticises Tweed's procedure. To quote, "Tweed's advocacy of a single measurement from the cephalometric film (is) a system of cephalometric appraisal which, by comparison, makes all other methods seem quite complicated."

Wylie feels that clinical orthodontists must avoid excessive reliance on average values, and that research workers dealing with clinical problems must eventually concentrate on individual cases, and deal with changes that mey be observed in individuals.

Dr Wylie, and Dr E.L.Johnson, studied before and after headfilms and photographs of 29 consecutive cases treated by Dr Tweed. They concur that Tweed undeniably improved the facial profile in his young patients, but feel that the improvement was largely due to the mandibular growth during the treatment period, and that in older patients similar tooth movements did not result in as great an improvement in the profile.

FINDINGS

(1) Treatment time averaged 13 months.

(2) Average Angular change of lower incisors 10.3° with an extreme of 24°

(3) Average uprighting of upper incisors 7.5 mms with an extreme of 18 mms (average angle 11°, extreme 28°.

Wylie and Johnson then considered individual cases to determine how uprighting the mandibular incisors is related to straightening the profile. They measured the "soft tissue angle of convexity" and found that the average straightening was 6.5°, the greatest change being 16°.

They found that there was no significant relation between the alteration in inclination of the mandibular incisors (or bodily lingual movement of mandibular incisors) and the soft tissue angle of convexity. However there was a definite relationship between retraction of the upper incisors and the soft tissue angle of convexity.

Buchin[22] reached a similar conclusion after study of 57 of his (Buchin's) treated cases.

Wylie comments that, in the 95 individuals whom Tweed[23] selected as having pleasing facial type, one thing was common to all - a well-developed mandible. Consequently they have relatively upright mandibular incisors.

Incidentally, as far back as 1940, Tweed[28] expressed his fondness for well developed chins.

In an article emphasising the futility of denture expansion, Strang [29] pointed out that, from Fauchard in 1723, expansion of dentures had been the basic form of treatment for the correction of malocclusions. After tracing the introduction of extraction techniques, Strang's conclusions are

(1) Every malocclusion represents a denture under the influence of, and stabilised by, balanced muscular forces which are inherent to the individual and unchangeable

(2) The muscular forces are two

(a) muscular tonus

(b) muscular contractions

(3) For successful treatment, the muscular balance must not be altered or upset.

(4) The key teeth in designating the tooth positioning that is harmonious with the muscular forces are the mandibular cuspids and first permanent molars

(5) The form of the maxillary denture and positioning of the maxillary teeth are governed by the mandibulardenture form and teeth positioning, established by adhering to the dictates of muscular balance.

(6) If it is impossible to position lower incisors over base bone without moving the mandibular cuspids labially and molars buccally, then extraction is definitely indicated.

(7) If muscular balance is preserved in treatment, result should be stable, and retention unnecessary.

There have been many articles describing methods of assessing cases to decide whether or not extractions are indicated.

In a good article Howes[30] describes how he studies models with his technique of "Model Analysis".

He lists two major requirements for treatment planning.

(1) An assessment of the possibilities of tooth movement.

(2) A prognosis of denture stability after treatment.

To assess the possibilities of tooth movement,Howes studies

(1) The size and form of the basal arches

(2) The relationship of the teeth to these arches

(3) The inter-relationship of the arches to each other.

(1) Size and form of basal arches.

Howes specially prepares three sets of models for each case and makes measurements on them. He states that arch space can be created in 3 ways,

(a) Expansion of dental arch (often results in relapse)

(b) Lengthening of dental arch (often produces "orthodontic look", or distal inclination of the second molars, and for impaction of third molars".

(c) Extraction (may result in spacing of teeth or a retruded appearance in the dental area)

(a) Howes' ideas on expansion are interesting (1) He feels that, in normal occlusion, there is a definite correlation between tooth material and arch width from 4| to |4, measured across the summit of the buccal cusps. He feels that this width should be slightly less than the width of the basal arch above the apices of 4|4 , andshould be at least 43% of the tooth material from 6| to |6 .

(2) The basal arches cannot be expanded (in the first premolar areas) after the eruption of the premolar, nor can we hope for any further lateral growth in this region. Actually Howes has found that there is frequently a decrease in basal arch width from 4| to |4 compared to D| to |D (probably due to a bulging of the labial plates to accommodate the unerupted cuspids and bicuspids).

(b) The second treatment procedure that Howes considers is distal movement of maxillary posteriors. Research indicates that there is little actual bodily distal movement of teeth in relation to skull anatomy (unless space is established by extractions). There is ubdoubtedly a distal movement in relation to the immediate supporting bone, but the teeth remain virtually stationary while the jaws grow downward and forward.

(c) Extractions. Howes considers these last. If expansion, distal movement, or a combination of both, are ruled out as unfeasible, then the choice is

(a) Leave case untreated

(b) Extract teeth.

Strayer [31] studies orientated head plate X-rays and uses them to assess

(A) The mandible

(1) Body length

(2) Body height

(3) Ramus and Condylar height also Ramus width

(4) The type of mandibular angle at the gonion

(5) Relation of dental units and their alveolar support to the body of the mandible; also the axial inclination of incisors

(6) The posture of the mandible

(B) Maxilla

(1) The Overall relation of the maxilla and maxillary denture to the mandible and mandibular denture

(2) The axial inclination of the upper incisors

(3) The amount of overjet.

Strayer also uses accurate models. He makes accurate measurements of the teeth and assembly size of the apical base by means of a " recording - plex".

From the data he thus accumulates, Strayer decides whether or not to extract.

Cheney [32] points out that it is important to determine what the patient desires - i.e. why he presented and what he hopes for in correction. In Cheney's experience, aesthetics are usually paramount to the patient. He says that where there is great discrepancy between teeth structure and supporting bone, extractions are obviously necessary, but the "borderline deficiency" cases need careful analysis. It is essential to recognise relationship between the teeth, the dental arches, and the supporting bone.

(1) The Apical base is fixed by the inherent growth pattern

(2) Alveolar Growth can be influenced somewhat during the growth period. In addition, it can be reduced, and this occurs when extractions are performed.

(3) The Dental Arch can be modified within the limits of its supporting alveolar bone. However, for a stable result, the arch must be shaped to conform to the supporting alveolar bone and apical base.

Cheney feels that arch form (teeth and alveolar bone) is important in the diagnosis of malocclusions, assisting in assessing the possibilities of

(a) Aligning and spacing of teeth

(b) Extracting and closing spaces.

He lists six types of arch forms

(1) Tapered

(2) Trapezoid

(3) Ovoid

(4) U- Shaped

(5) Hyperboloid

(6) Square

(1) Tapered If tooth substance exceeds base bone, extractions are indicated, as expansion would produce an unstable result. If extractions are well - timed, treatment time can be minimised.

(2) Trapezoid : converges in variable degrees from molars to cuspids, and are

abruptly rounded from cuspid to cuspid. Here there is greater width in premolar and cuspid areas and consequently more room for manipulation of teeth. In borderline deficiency cases, a certain amount of expansion is possible. Here examination of the parents, and other members of the family, can assist. Moore and Hughes [33] reported the extensive influence of heredity on the production of features in the dentofacial complex. In their analysis of arch form they state that each form is strongly dependent upon heredity circumstances, with a general dominance of narrow or restricted arches over broad ones. For example, if a long tapering arch is present in both parents, expansion of the child's arch is not indicated.

However, if medium to large dental arches are present in both parents, aligning and spacing can be considered in terms of favourable results.

(3) Ovoid arch

Greater opportunity for alignment of all the teeth

(4) U-Shaped arches

The jaws are usually large, and the alveolar bone massive. Extraction is rarely resorted to. Irregularities are usually of local, rather than deep seated causes. Martinek[34] compared various methods of assessing the adequacy of basal bone.

Hayes, Nance[35], Carey,[36] and Ballard and Wylie[37] have suggested various methods for analysing the mixed dentition to predict whether there would be adequate accommodation for all the adult teeth. However, Martinek says that (a) conditions such as parallax and (b) the uncertainty of growth have resulted in these methods not being widely accepted.

Martinek then considers methods of analysing the adult dentition to appraise the adequacy of supporting bone. He analysed five consecutive patients, using the methods suggested by Stayer,[31] Howes[30], Rees,[38] and Kesling[39].

Rees' method involves both maxilla and mandible. He compares

1. The upper base with upper teeth
2. The lower base with lower teeth
3. The upper base with lower base
4. The upper teeth with lower teeth

In studying 20 "normal" cases, Rees found

(1) Upper base exceeded upper teeth by 1.5 - 5 mms

(2) Lower base exceeded lower teeth by 2 - 7 mms

(3) Upper base exceeded lower base by 3 - 9.5 mms

(4) Upper teeth exceeded lower teeth by 5 - 10 mms.

When diagnosing a case, Rees decides whether extractions are necessary by the degree of disparity between the measurements of base and tooth structure.

Kesling popularised the " diagnostic set-up". His present method of performing this entails a technique similar to that of Tweed [23]. He draws a line on a lateral cephalogram, from the apex of the mandibular incisor to intersect the Frankfort plane at an angle of 65°. He then measures the distance in millimetres from the incisal edge of the incisor to this line. This tells the number of mms the mandibular incisors must be tipped lingually. Kesling saws the teeth from the model, then waxes the mandibular incisors back onto the model. He then waxes on the remaining mandibular teeth. The maxillary teeth are then sawed from their model and set up in wax to occlude with the lower teeth.

He thus decides whether there is sufficient room to accommodate all the teeth.

Martinek proceeded to analyse five consecutive patients, using in each case the method of analysis suggested by Howes, Strayer, Kesling, and Rees.

The results are tabled

Analysis	PATIENTS. 1	2	3	4	5
Howes	Extraction	Non-extraction	Non-extraction	Extraction	Borderline
Rees	Borderline	Non-extraction	Borderline	Extraction	Borderline
Kesling	Extraction	Non-extraction	Non-extraction	Extraction	Extraction
Strayer	Borderline	Non-extraction	Non-extraction	Extraction	Non-Extraction

Results.

Case I

Martinek extracted and encountered a great space-closure problem.

Case II

This case was completed with a deep overbite and slight protrusion. However Martinek is sure that extracting would have produced an even less satisfactory result.

Case III

No extraction and case proceeded satisfactorily.

Case IV

Extractions performed with satisfactory results.

Case V

No extractions. Case satisfactory, but some residual irregularities.

White [4] states that the aim of orthodontic treatment is to restore the teeth in a given mouth to the utmost in

Efficiency

Longevity

Harmony

Beauty

Stability

He feels that the number of teeth remaining after treatment is relatively unimportant. The principles of jaw and facial growth must be applied to the appraisal and diagnosis. Brodie [40] has shown that the growth pattern, established during the first year of life, does not change throughout the life of the individual. In normal patterns the growth vector is downward and forward. In abnormal pattern, growth may take a different direction, but will continue in that direction as a given course.

Berger [41] states that in the majority of orthodontic cases, there is a discrepancy between the size of the jaws and teeth, or between the sizes of each jaw, or a combination of the two. Berger has listed three possible causes for these discrepancies

(1) A Pathologic Basis where disease or injury has dwarfed the growth of the jaws

(2) A Constitutional - Hereditary Basis ; Inheritance of large teeth and small jaws or vice-versa

(3) A Phylogenetic basis ; The evolutionary transition from the massive Neanderthal jaws to the much smaller jaws of modern man has been much greater in proportion than the transition of the sizes of the teeth.

Brodie [42] cautions against a hasty presumption of insufficient bony structure for all the teeth, and says "The rate of eruption and growth in each individual may have many varying possibilities in their relation to each other. Also the magnitude of disharmony in each case may range from easy to difficult to judge" .

Salzman [43] mentions alveolar prognathism as one of the primary factors determining the need for extractions. This may occur with or without true basal prognathism.

Von der Heydt [44] discusses alveolar prognathism that exhibits Class II div. I characteristics. He designates four types of Maxillary Protrusion

(1) True Maxillary Protrusion

(2) Maxillary Protrusion with mandibular insufficiency

(3) Potential Maxillary Protrusion

(4) Mandibular Displacement for Class I cases of alveolar prognathous type.

Von der Heydt differentiates

(1) Classical Bimaxillary Protrusion

(2) Potential Bimaxillary Protrusion

Bercu Fischer [45] who differentiates five types of Class II Div. I malocclusion (Angle) only recommends the extraction of four bicuspids in Bimaxillary Protrusions. In other types, if extractions are carried out, Fischer recommends extraction of maxillary second or third molars and distal movement of the teeth anterior to the extraction space, using extra-oral traction. I like Fischer's method of treating Class II cases.

Graber [46] describes treatment of Class II cases by extraction of maxillary second molars, and extra oral traction. The cases most suitable for this procedure, in his opinion, are those where

(1) There is excessive labial inclination of the maxillary

incisors, with no spacing

(2) Overbite is minimal

(3) Maxillary third molars are present, in good position and proper shape.

Begg [47] states that anthropologists, observing the increase in tooth crowding in modern man compared with primitive man, have blamed evolutionary reduction in jaw size. However, Begg feels that a more important reason is lack of attritional interproximal tooth wear with modern diet. He feels that mot enough attention has been paid to variation in tooth size and points out that tooth size and jaw size are separate entities and both are variables in the problems of malocclusion. In 1934 he measured the width of the upper four permanent incisors of 156 children.

110 had crowding and average of incisors measured 30.9 mms.

46 had no crowding and average of incisors measured 29.3 mms.

He also measured the teeth of 52 "pre-white" aboriginal skulls and found

21 had crowding, average of incisors measured 36.86 mms.

31 had no crowding, average incisors measured 34.6 mms.

In the "pre-white" skulls, Begg found Class II and Class III malocclusions, , but attritional wear eliminated the milder forms of Class I malocclusions.

Begg's recommendations for extractions for orthodontic purposes are

(1) In cases where the preponderance of tooth structure would have been eliminated by ATTRITION in stone-age man, then extract four first bicuspids except in very mild cases, where expansion may be sufficient.

(2) In cases where there would have been crowding, overlapping, or "double protrusion" even with the extensive attrition produced by stone-age man's diet, then Begg usually extracts four first bicuspids. However, in some cases, Begg extracts further teeth due to extreme discrepancy. In these cases

(a) If child presents at age 7 to 9, Begg has all first permanent molars extracted immediately, then defers active treatment till all permanent teeth (except third molars) erupt. Then four first bicuspids are extracted, and banding commenced.

(b) If child presents later, all first bicuspids and first molars are extracted before active treatment. Sometimes the second molars are allowed to migrate mesially before placing appliances, because Begg feels that there second molars are then more in conformity with their " true anatomical position" (second molars in stone-age man are further forward, due to approximal attrition, than in " text - book normal occlusion").

Begg's recommendations are extreme. However, they find some indirect support in the literature. He quotes B.L.Herzberg[48] who describes cases where, after extracting four first bicuspids, all the extraction space is needed, or is insufficient. These cases are difficult to treat, and it is difficult to retract the anteriors without moving forward the teeth posterior to the extraction space. These are the cases in which Begg extracts eight teeth.

In difficult Class II cases, Begg often proceeds as follows

(1) To overcome an excess of tooth substance, four first bicuspids are extracted.

(2) Because of very marked antero-posterior malrelation of jaws, Begg extracts upper first molars. At end of active treatment, upper 7s occlude with lower 6s , and upper 8s with lower 7s. After treatment lower 8s are extracted as they have no opposing antagonists.

Margolis[13] studied the Incisor Mandibular Plane Angle and suggested that the crowding of mandibular incisors, which frequently followed treatment by arch expansion, was due to "straightening up" of mandibular incisors,(and not due to pressure from erupting 3rd molars as was previously suggested). Margolis cited a case where the angle changed from 101° to 116.5° during treatment, and one year later had returned to 106°.

Brodie[42], using cephalometric x-rays, found that in two extraction cases which he studied, the forward movement of molars exceeded the backward movement of incisors, and that the incisors, uprighted during treatment, tended to relapse forward after treatment.

Cole[49] then analysed 21 cases, treated with Edgewise appliances, in each of which 4 first bicuspids were extracted as part of the treatment. Complete tracings were made from cephalometric headplates taken at the beginning and end of treatment, and also at least one year after removal of retention. He found that

(1) Space closure is accomplished by anterior movement of molars, and posterior movement of incisors. In 50% of cases, predominantly anterior movement of molars: in 25% of cases, predominantly posterior movement of incisors : in 25% of cases equal movement of both.

(2) Posterior movement of mandibular incisors can either be a tipping or bodily movement.

(3) There appears to be a strong tendency for the mandibular incisor - mandibular plane angle to revert to its original dimension after treatment.

(4) Treatment involving extractions tends to increase the overbite. Cole found this in 62% of cases.

(5) Overbites reduced by treatment tend to return.

Cole remarks that the question of overbite has had little attention in the extraction controversy, although a deep overbite is considered undesirable. Cole's findings also confirmed the findings of Brodie et al[20], that only the alveolar bone can be modified by treatment. The basal bone remained unaltered.

However, Urban[50] has reported reductions of up to $1\frac{1}{2}^{\circ}$ in S.N.A., using extra - oral traction and Buchin[22] claims reductions of up to 5° in S.N.A. , using Class II elastics and prepared mandibular anchorage. However an error in estimating the position of "Point A " could influence these figures.

Buchner[51] lists some of the criticisms that have been directed at some of the results of treatment, when teeth have been extracted.

(1) Tooth roots not parallel, resulting in pocket formation.

(2) A loss of bone structure in the area of extraction, causing what has been called an aging of the denture.

(3) Failure to completely close and hold contacts

(4) The extractions have left the face deficient in the denture area.

He agrees that much care must be exercised during treatment in order to prevent these results, and reiterates that extracting must not be considered an " easy way out ".

In another article, Buchner[52] speaks against the Tweed Philosophy. While allowing that, in some cases, it is necessary to change the inclination of the incisors markedly, he feels that the final pattern should fit harmoniously into the structures of the face according to type. To quote " To always place the lower incisors in relation to the mandibular lower border according to a fixed formula is to ignore the extremes in facial types, and discrepancies between maxillary and mandibular structures ".

Fischer[45] points out that Angle did not consider mandibular incisor inclination in his classification. In Fischer's practice, the angle in Class II Division I cases varies from 80° to 105°, but he points out that this range is no greater than that found by Noyes, Rushing, and Sims[53] in individuals with acceptable occlusions. Fischer does not attempt to upright the mandibular incisors, except in Bimaxillary Protrusions.

One orthodontist who still pronounces against extractions is Alexander Sved[54]. In a 1948 article he showed photographs of an extreme bi-maxillary protrusion case which he treated without extractions, and achieved a stable result. However, the aesthetics of this case would not be considered pleasing by most orthodontists.

In 1956 Sved[55] stated that he has not found it necessary to extract a tooth in 37 years of practice. He admits that expansion cases treated without extractions are protrusive at the end of active treatment. However, he claims that, at the end of active treatment, the case is not completed, and beneficial growth during the retention period results in improvement of the occlusion and jaw relationships during retention. However Pelton and Elsasser[56] studied 6,829 subjects whose ages ranged from 8 to 24 years, and concluded that the face becomes more convex with age. To quote " The facial profile will not straighten with growth. Thus the orthodontist cannot hope that the profile will improve with age without orthodontic intervention ".

Sved uses Vitallium Adjusters for retention and claims that these promote development of the alveolar processes. He presents a series of 50 cases, and the occlusion and jaw relationships are definitely improved at the end of the retention period (usually about 2 years). <u>However</u>, Sved does not show any photographs of cases several years out of retention, and I would be interested to see these.

A different approach to the orthodontic treatment is evidenced by H.Chapman[57]. Chapman has written a good article with some important points. However the essence of his treatment planning is to avoid using appliances if possible as he feels that, the less appliances used, the better for oral health. He extracts a tooth in poor condition, rather than a sound one, and recommends extraction of a badly-placed tooth rather than one in good alignment e.g. a rotated lateral rather than a first bicuspid. He does not feel that symmetrical extractions are necessary and extracts selected teeth to avoid appliances, but the photos of his treated cases are not impressive. He states that if a tooth is extracted for another to replace it, there should be an excess of space of about 2 mms., as there is frequently a loss of space in such cases. Some of Chapman's suggestions for extractions are

(1) An upper central incisor may be extracted due to its position or trauma. If apical base is small, the space can be easily closed, but if basal bone is adequate space closure may be difficult.

(2) In cases with small basal bone and considerably prominent upper centrals, Chapman recommends exn of 2|2 and retraction of 1|1 . He also recommends unilateral extraction of |2 or |3 if the |3 is blocked out, depending upon the residual space available. I feel that these techniques leave much to be desired, and that bilateral bicuspid extraction, followed by appliances should be carried out. Although the economic factor would probably be more important in Britain than in Australia or the U.S.A., I feel that orthodontists should aim at as high a standard of treatment as they are capable of, instead of using oversimplified methods.

(3) Chapman recommends extraction of a badly decayed 6 instead of a sound bicuspid and I feel that this is very sound, provided that space closure can be effected.

An important point made by Chapman is the fact that arches are interdependent. They must be considered together. The size of the lower dental arch controls the size of the upper dental arch. Loss of a lower tooth is followed by a reduction in size of the lower dental arch. This results in a contraction of the upper arch. An example of this is where the lower incisors are crowded, but the upper incisors are in good alignment. If a lower incisor is extracted the remaining lower incisors will straighten, but because of their contracting together we see a resultant contraction of the upper arch and crowding of the upper incisors.

However, if no teeth are removed from the lower arch, its size remains constant; and if teeth are now removed from the upper arch, its size will remain constant but teeth can be moved around the arch, and spaces closed.

Weber[58] also cautions against extracting a mandibular incisor, as he says that it will increase the overbite. He excepts certain open-bite cases where bite closure is desired. One case where extraction of a lower incisor may be considered is in the treatment of true Class III cases. Hahn[84] has recommended this, enabling the width of the mandibular arch to be reduced, and some lingual movement of the mandibular incisors to be accomplished. It is also possible to obtain some desirable bite-closing. Strang[10] is enthusiastic about this procedure in selected cases.

Martinek[59] also suggests that premolar extractions and anterior movements of molars can assist in the closure of open-bite cases.

Bull[60] claims that a great percentage of Class II Div. I cases, treated with Class II elastics result in one of two undesirable results - either a "Dual Bite " or a double protrusion. He treats <u>all</u> Class II Div. I cases by extracting four first bicuspids. He closes the spaces using sectional arches with closing loops and uses Class II elastics, his aim being to ensure that the lower incisors remain vertical over base bone.

However Goldstein is not pleased with this method and feels that a slight forward inclination of the lower incisors is not always too drastic a result. Goldstein feels that to routinely extract four first bicuspids in Class II Div. I cases can surely only be justified where a double protrusion already exists before treatment, and I agree with him.

Serial Extraction as a Treatment Procedure.

Lloyd[62] defines serial extractions as "An early recognition or anticipation of a deformity that will occur unless teeth are removed at stragetic intervals, to relieve in intensity the developing malocclusion ".

Lloyd points out that although Kjellgren of Sweden and Heath of Melbourne have been practising serial extractions for twenty years, it has not been widely recommended in U.S.A. until recent times.

Foster[63] discussed changes occurring in the mandibular arch after extraction of lower deciduous canines in those cases showing lack of intercanine width.

Kelly[64] recommended serial extractions of deciduous teeth to prevent and overcome rotations of incisors.

Lloyd[65] recommended serial removal of teeth, both deciduous and permanent, based on the sequence of eruption of the permanent teeth.

Dewel[66] recommends serial extractions, provided that the indications are correct, and that the post-extraction shiftings are controlled by mechanical means. These cases are usually characterised by

(1) Shortened arches

(2) Blocked - out or malposed incisors

(3) Shift in the Median Line

(4) Frequently, early loss of one or both deciduous mandibular cuspids.

(5) Molars usually in Class I relation

(6) Facial contours and dental appearance usually still acceptable.

Dewel recommends the following treatment procedure

(1) Preliminary observation period (sometimes a favourable growth

trend may be observed).

(2) Serial extractions at the correct time

(3) A short period of active appliance therapy.

Dewel points out that John Hunter in 1771 stated that there is no increase in length from $\overline{6|6}$ after the eruption of the 6s , and the jaws subsequently lengthen only at their posterior end. Brodie[67] confirms this, and Moore[68] demonstrates the same phenomenon in the maxilla. Dewel also quotes Sicher[69] that there is no possibility of internal expansionof the mandibular supporting structures by "interstitial growth of bone".

Lloyd[62] lists malocclusions where serial extractions are

(a) INDICATED

Class I or Class II Division I malocclusions that show in both maxilla and mandible

(1) A severe lack of arch length

or (2) A severe lack of intercanine space

(b) CONTRA - INDICATED

(1) Class II Div. II cases

(2) Class III cases

(3) Cases where first permanent molars are heavily restored

(4) Cases where there are congenitally absent or malformed second bicuspids.

Lloyd describes in detail the procedure for serial extractions.

The four deciduous cuspids are removed after the eruption of the mandibular permanent laterals. This phase is referred to as the "period of incisor adjustment".

Foster[63] supports the contention that the posterior teeth do not move forward when the deciduous cuspids are extracted.

The next phase is the "period of canine adjustment". It is necessary to decide the best time to remove the four first premolars to permit the most favourable adjustment of the four permanent canines. Lloyd determines this by X-ray examination approximately one year after the extraction of the four decidious canines.

There are three possibilities

(1) If the 3 is erupting before the 4, then the D and the unerupted 4 are extracted. This occurs rarely in maxilla, but in 60% of mandibular arches.

(2) If 3 and 4 are erupting at the same rate, the D is removed to permit the 4 to erupt before the 3. When the 4 erupts, it is extracted.

(3) If 4 is erupting before 3, then D is allowed to exfoliate, and when 4 erupts, it is extracted.

The third molars have been the subject of several papers.

Kelsey Fry[70] and H.Davis[71] both implied that the dentist has failed in his duty if a lifelong patient, seen at regular intervals, develops impacted lower third molars. However Rothenberg[72] feels that it is impossible to predict what course the growth and development of the face and jaws will take. Broadbent[73] says that individuals, in spite of early setbacks to their growth and development, may recover and ultimately attain sufficient size to accommodate all their teeth. Rothenberg does not believe that early removal of third molar buds is justified, as he feels that one cannot predict from the position of the developing third molar whether or not it will erupt normally.

Hillen[74] states that the size of the teeth has not decreased in ratio to the seeming evolutionary decreasing size of the arches and consequently the third molar becomes "impacted" due to lack of space for its normal eruption, and appea rs to create a form of compression or displacing pressure throughout the entire dental arch.

However Broadbent[75] studied growth from serialised standardised cephalometric radiographs and concluded that any buckling of the lower dental arch at the time of eruption of the third molar is due to lack of adequate growth and development of the mandible. Consequently Broadbent felt that both the impacted third molars and crowded incisors are victims of underdeveloped skeletal structure.

Eggnatz[76] suggests diagnostic aids in X-ray interpretation to assess whether the third molars will erupt normally.

(1) MAXILLA Study the mesiodistal width of the upper 8 as compared with the bony area of the tuberosity at about 16 years of age.

(2) Mandible Study the root formation of the 8. If root formation is complete and the tooth unerupted, then it is possible that the tooth will not erupt.

Strang[10] lists factors in deciding which teeth to extract in extraction cases.

(1) The classification of the malocclusion.

Class I. Here four first bicuspids are usually extracted, and distal movement of the anterior teeth (plus some forward movement of posterior teeth) usually completes the treatment.

Class II Distal movement of the maxillary teeth is necessary, coincident with space closure. In older patients, it may be indicated sometimes to extract upper first bicuspids only, and close the space, leaving lower arch intact. This method has also been mentioned by Von der Heydt[44], Graber[77], Rosenstengel[78], Jackson[9] and others. It must be considered a compromise treatment and should be completed by occlusal equilibration by selective grinding. Graber[46] feels that it is better to have molars in Class II relation than to be edge to edge and feels that "too much stress has been placed on a Class I buccal segment relationship regardless of the degree of apical base dysplasia".

Class III Extractions are rarely indicated. However Strang suggests that occasionally it may be indicated to extract one mandibular incisor, and place this reduced mandibular arch in lingual relation to the maxillary anterior teeth.

(2) How much distal movement is required.

This is best determined by studying the facial lines of the patient, and also his photographs.

(3) Which teeth to be extracted.

Usually four first bicuspids, because they are in juxtaposition to the six anteriors to be moved lingually and distally. However, a badly displaced tooth such as $\overline{5|5}$ may be better extracted. Extreme caries may indicate another tooth. Strang feels that this is the only reason for extraction of first permanent molars. Extraction of first permanent molars is rarely mentioned in American Journals. However in Australia it is practiced fairly frequently, probably due to orthodontists here having to treat cases where the six-year old molars have a very poor prognosis. Henry[79] describes a technique for treating Class II cases where the second permanent molars have erupted. The maxillary 6s are extracted, and a bite plate inserted, with springs exerting distal pressure on the upper bicuspids. When the bicuspids have been moved more than half the required distance, the arch is banded, and intra-maxillary elastics are used to complete the space closure, and retract the incisors. This technique is suitable for cases where there is little or no crowding in the mandibular arch.

(4) At what stage of treatment extraction best performed?

Tweed and Strang believe in banding the teeth, then extracting the selected teeth, then placing the arches after two days. Sometimes a tooth is retained for anchorage and extracted at a later stage in treatment. However I feel that it is better to extract and then wait for a few months to permit the teeth to drift part of the way. This minimises the time the fixed appliances are in position and applies particularly to Class I cases.

Silver[80] presents a case report in a paper entitled "Autonomic orthodontics". He actually carried a programme of serial extractions on a case where there was crowding in the deciduous dentition and produced a very acceptable result without placing any appliances.

Strang feels that only a small % of Class II cases need extraction. This particularly applies to Class II Div. II cases. However in bimaxillary Class II cases, or cases where buccal segments are overlapping incisors because of insufficient base bone, extractions are required.

Several cases are reported in the literature where extractions are used in the treatment of Bimaxillary Protrusions. Fischer[81] shows before and after photographs of such a case, demonstrating a dramatic improvement in facial harmony.

Spring[82] describes the treatment of bimaxillary protrusions.

Dewel[83] describes the indications for extracting four second bicuspids in treatment. This is indicated in certain borderline deficiency cases. In these cases, the diagnosis usually depends on the mandibular arch. The incisors and cuspids are crowded and one or more may be blocked out of the arch. The maxillary arch may be quite regular and give no indication that extractions would be needed, except to enable a correct molar relationship to be attained with the mandibular arch. In these cases, the eight anterior teeth are pitted agains the molars. This lessens the probability of the anteriors being tipped too far lingually during treatment, then after the appliances are removed the teeth reverting to their typical upright position, and spaces recurring throughout the arch. (This can happen if first bicuspids are extracted in borderline cases)

After extracting the second bicuspids, the eight anterior teeth are pitted against the first molars until the space is closed. The second molars which will have drifted forward (tipping in the mandibular arch) are then banded and uprighted.

I feel that this technique is a good one for this type of case. Extraction of four first permanent molars has been advocated by Wilkinson[85] and others. Wilkinson maintains that 99% of Anglo-Saxon mouths are overcrowded. He recommends extraction of the four first permanent molars to prevent overcrowding and its sequelae. Salzmann condemns this procedure and surveyed nearly 2000 children, aged 15-19 years, all of whom had had one to four 6s extracted. He found that the shifting of teeth due to the extractions led to traumatic occlusion, gingival affections, and especially in the maxilla actually increased the caries incidence. Routine extraction of four first permanent molars without subsequent orthodontic treatment must be condemned.

Osborne[86] describes a case where a mandibular incisor was extracted. The posterior teeth were in correct occlusion, but due to discrepancy in tooth sizes between maxillary and mandibular teeth, the upper anteriors were spaced, and the lower anteriors were crowded. Because the lower left cuspid was forced out of the arch, the lower left central incisor (slightly denuded laterally) was chosen for extraction.

The alignment of the mandibular incisors permitted closing of the spaces in the maxillary anterior segment. Photographs taken 2½ years after treatment show a stable result. The upper arch was retained for 1 year, but no retention was used on the mandibular arch.

Osborne reiterates that it is necessary to consider any discrepancy in tooth structure between maxillary and mandibular arches.

I feel that Osborne used a logical approach here, and that the extraction was justified - the key point being the discrepancy in tooth structure between the arches.

R E F E R E N C E S.

1. Weinberger, Bernard W. : From Irregularities of the Teeth to Orthodontics, A.J.O. 42: March 1956.
2. Case, Calvin S. : The Question of Extractions in Orthodontia, Dental Cosmos Feb.March,Sept, 1912.
3. Angle,E.H. : Malocclusion of the Teeth, 7th ed. Philadelphia , S.S.White, 1907.
4. White, Robert B. : Some Viewpoints on Extraction, A.J.O.40: July 1954.
5. Fairbanks,L.C. : Research and Etiological Concept of Malocclusion. A.J.O.34: 192 1948.
6. Angle E.H. : Bone-Growing, Dental Cosmos.52: 261.1910 (Reported by White)
7. Brodie,A.G. : Appraisal of Present Concepts in Orthodontia, Angle Orthodontist 20: 24 1950.
8. Jackson, Andrew F. : Orthodontic Objectives,A.J.O. & O.S. 28,486-512 1942.
9. Jackson, Andrew F. : Simplicity in Orthodontic Concept and Treatment, A.J.O. and O.S. 36: 643 Sept 1950.
10. Strang,R.H.W. : A Text Book of Orthodontia. 1950.
11. Broadbent, B.H. : A New X-ray Technique and its Application to Orthodontia. Angle Orthodontist 1. 45 1931.
12. Tweed, C.H. : Indications for Extractions in Orthodontic Treatment, A.J.O. 30: 405 1944.
13. Margolis, Herbert I. : The Axial Inclination of Mandibular Incisors, A.J.O. & O.S. 29: 571-594 1943.
14. Tweed, C.H. : A Philosophy of Orthodontic Treatment, A.J.O. & O.S. 31: 74-103 Feb 1945.

15. Herzberg, B.L. : The Tweed Formula, Anchorage Preparation, and Facial Aesthetics, Angle Orthodontist 24: 170-177 July 1954.

16. Tweed C.H. : Indications for Extractions in Orthodontic Therapy, A.J.O. 30: 405, 1944.

17. Dinham, George A. : Treatment Aims and Limitations, A.J.O.34: 171.1948.

18. Speidel,T.O.,Stoner and Morris: Variations of Mandibular Incisor Axis in Adult "Normal" Occlusion.A.J.O.& O.S. 30: 536-542 1944.

19. Brodie, A.G. : 18 Years of Research at Illinois, Angle Orthodontist Jan. amd April 1948.

20. Downs,Goldstein,Meyer, & Brodie : Cephalometric Appraisal of Orthodontic Results. Angle Orthodontist 8 : 261-351 1938.

21. Tweed,C.H. : Frankfort-Mandibular Plane Angle, A.J.O.& O.S. 31 :175-220 1946.

22. Buchin, I.D. : An Appraisal of the Effect of the Edgewise Arch Appliance in Modifying the Dentofacial Profile,A.J.O.43 : 11 Nov. 1957.

23. Tweed, C.H. : The Frankfort-Mandibular Incisor Angle (F.M.I.A.) in Orthodontic Diagnosis,Treatment Planning and Prognosis, Angle Orthodontist 24 : July 1954.

24. Schwartz, Harold : The Norm Concept, its Use and Abuse, Angle Orthodontist 23 : July 1953.

25. Downs, William B. : Variations in Facial Relationships, A.J.O.34: 812 1948.

26. Brodie,A.G. : Late Growth Changes in the Human Face. Angle Orthodontist 23 : July 1953.

27. Wylie, W.L. : The Mandibular Incisor - it's Role in Facial Aesthetics, Angle Orthodontist 25: 32-41 Jan.1955.

28. Tweed, C.H. : The application of the principles of the Edgewise Arch in the treatment of Malocclusion. Angle Orthodontist 11: 5 1941.

29. Strang, R.H.W. : The Fallacy of Denture Expansion as a Treatment Procedure, Angle Orthodontist Vol.XIX No.1 Jan 1949.

30. Howes, Ashley : Model Analysis for Treatment Planning, A.J.O. 38 : 183 March 1952.

31. Strayer, Edward Ray. : Procedures for Case Analysis and Evaluation. A.J.O. 38 737 October 1952.

32. Cheney, E.A. : Some considerations on the diagnosis of Malocclusion relative to Extractions, A.J.O. 36: 19 Jan.1950.

33. Moore, G.R., Hughes, B.O. : Familial factors in Diagnosis Treatment and Prognosis of Dentofacial Disturbances, A.J.O. 28: 603 1942.

34. Martinek, C.Edward : A comparison of Various Surveys on the Adequacy of Basal Bone, A.J.O. 42: 244 April 1956.

35. Nance, Hayes V. : Limitations of Orthodontic Treatment, A.J.O.& O.S. 32 : 177-223, 253-301 1947.

36. Carey, C.W. : Linear Arch Dimensions & Tooth Size, A.J.O. 35: 762-775 1947.

37. Ballard, M.L. & Wylie, W.L. : Mixed Dentition case Analysis - Estimating Size of Unerupted Teeth, A.J.O. & O.S. 33: 754-759 1947.

38. Rees, Denton J. : A method for Assessing the Proportional Relation of Apical Bases and Contact Diameters of the Teeth, A.J.O. 39 : 695-706 1953.

39. Kesling, H.D. : The Philosophy of the Tooth Positioning Appliance, A.J.O. & O.S. 31: 297-304, 1945.

40. Brodie, A.G. : Observations on the Growth Patterns of the Human Face, and their implications to the Orthodontist, A.J.O. 26 : 741 1940.

41. Berger, H. : The problem of extraction in Orthodontics, A.J.O.31 : 557, 1945.

42. Brodie, A.G. : Does Scientific Investigation support the extraction of teeth in Orthodontic Therapy ?. A.J.O. 30 : 444 1944.

43. Salzmann, J.A. : Criteria for Extraction in Orthodontic Therapy related to Dent-Facial Development, A.J.O. 35 : 584 1949.

44. Von der Heydt, K.E. : An analysis of the Clinical entity, Maxillary Protrusion, with relation to Classification, diagnosis, and treatment, A.J.O. 37 : 842 1951.

45. Fischer, Bercu : Orthodontics, Diagnosis, Prognosis, Treatment, W.B.Saunders 1952.

46. Graber, T.M. : The Role of Upper Second Molar Extraction in Orthodontic Treatment, A.J.O. 41 : 354-361 May 1955.

47. Begg, P.R. : Stone-Age Man's Dentition, A.J.O. 40 : 4, April 1954.

48. Herzberg, B.L. : The application of the Edgewise Arch Mechanism to the Tweed Philosophy in Orthodontics, A.J.O. 38: 516 1952.

49. Cole, H.J. : Certain Results of Extraction in the treatment of Malocclusion, Angle Orthodontist 18: 103, July, October 1948.

50. Urban, W.O. : A Cephalometric Study of Orthodontic Treatment using Upper Appliance with Occipital Anchorage, ANGLE Orthodontist 25: 61-76 1955.

51. Buchner, H.J. : An Answer to some criticisms of treatment following Bicuspid Extractions, Angle Orthodontist 19: 23-47 Jan. 1949.

52. Buchner, Howard J. : Closing Spaces in Orthodontic Cases, Angle Orthodontist 23 : 158-175 July 1953.

53. Noyes, H.J., Rushing C.H., and Sims, H.A. : The Angle of Axial Inclination of Human Central Incisor Teeth. Angle Orthodontist 13: 61. 1943.

54. Sved, A. : Treatment of Malocclusion, A.J.O. 34 : 549-579 July 1948.

55. Sved, A. : The Problem of Extraction, A.J.O. 42 : July 1956.

56. Pelton, W.J., & Elsasser, W.A. : Studies in Dento-Facial Morphology, II Profile Changes Among 6829 White Individuals According to Age and Sex, Angle Orthodontist 25 : 199-207, 1955.

57. Chapman, H. : Extraction as an Orthodontic measure. I.D.Journal, Vol.1, No.2, Dec. 1950.

58. Weber, F.N. : Prophylactic Orthodontics, A.J.O. 35 : 16 1949.

59. Martinek, C.E. : Orthodontia's Last Decade of Progress, A.J.O. 31: 161, 1945.

60. Bull, Harry L. : Obtaining Facial Balance in the Treatment of Class II Div. 1, Angle Orthodontist XXI : 139-148 July 1951.

61. Goldstein, A. : A discussion of Dr Bull's paper. Angle Orthodontist XXI 149- 150. 1951.

62. Lloyd, Z.Bernard, : "Serial Extraction as a Treatment Procedure". A.J.O. 42 : 728 October 1956.

63. Foster, H.R. : "An Analysis of the Developing Dentition". J.A.D.A. 42: 376-387.

64. Kelly, Eugene J. : Treatment in the Mixed Dentition. Angle Orthodontist 20 : 102-108 1950.

65. Lloyd, Z. : A Composite report of Class I Malocclusions with insufficient arch length. A.J.O. 39: 262-267 1953.

66. Dewel, B.F. : Serial Extraction in Orthodontics. A.J.O.40: 906-926, Dec.1954.

67. Brodie, A.G. : "On the growth of the jaws and eruption of the teeth " Angle Orthodontist 12: 109-123 1942.

68. Moore,A.W. : "Head growth of the Macaque monkey as revealed by vital staining, embedding, and undecalcified sectioning", A.J.O. 35: 654-671 1949.

69. Sicher, Harry : "The growth of the mandible ". A.J.O. & O.S. 33: 30-35 1947.

70. Fry, Kelsey. : British Dental Journal,April 1933.(reported by Rothenberg).

71. Davis, H. : J.A.D.A. May 1932. (reported by Rothenberg).

72. Rothenberg, Fred. : "The lower third molar problem". A.J.O. & O.S. 31: 104 Feb. 1945.

73. Broadbent, B.Holly. : Ontogenic Development of the occlusion, Angle Orthodontist 11: 223, 1941.

74. Hillen, Glen R. : Indications for removal of impacted third molars at an early age. A.J.O. & O.S. 33: 302, 1947.

75. Broadbent, B.Holly. : The influence of the third molar on the alignment of teeth. A.J.O. & O.S. 29: 312-330, 1943.

76. Eggnatz, Meyer. : Third molar considerations. A.J.O. 36: 445 June 1950.

77. Graber, T.M. : "New horizons in case analysis"- Clinical cephalometrics". A.J.O. 1952.

78. Rosenstengel, B.L. : A method of treating Protrusion of the upper arch in Class II Division I Malocclusion. Dent. J. of Aust. 1951.

79. Henry,R.G. : The Extraction of the Upper First Permanent Molar in the treatment of Class II,Div.I (Angle) Malocclusions. Aus.Dent. Jour.1: 211 1956.

80. Silver, E.J. : "Autonomic Orthodontics". A.J.O. 42: 54-58 January 1956.

81. Fischer, Bercu. : "Report of a case of Bimaxillary Protrusion" with unilateral Class II molar relationship in which four first premolars were extracted as part of the treatment plan. Angle Orthodontist XIX 106-111 April 1949.

82. Spring, D.F. : Bimaxillary Protrusion . Dent. J. of Aust. 1951.

83. Dewel, B.F. : Second Premolar Extraction in Orthodontics : Principles, Procedures, and Case Analysis. A.J.O. 41 : 2. Feb.1955.

84. Hahn, G.W. : Problems in the treatment of Malocclusion. Angle Orthodontist XII April 1942.

85. Wilkinson, L.W. : Factors contributing to facial Growth and Development. A.J.O. & O.S. 26 : 1019 1940.

86. Osborne, Donald D. : Removal of a Lower Incisor. A.J.O.38: 843 1952.

GROWTH AND DEVELOPMENT.

<u>Growth</u> has been defined by Huxley as " the self-multiplication of living substance". Tissue growth is accomplished by cell division and consequent increase in the number of cells.

Skeletal growth continues until about the twentieth year. Growth in stature ceases when the epiphyses close.

Protoplasm is the essential component of the body cells. It contains carbohydrates, fats, and amino-acids. Salzmann[1] concludes that growth requires synthesised food including proteins, fats, carbohydrates, vitamins, and other elements.

<u>In newborn child</u> , body weight is made up of

35% organs and blood

10% bone

20% muscle

35% fat.

<u>In adult</u>

20% organs and blood

20% bone

40% muscle

20% fat.

Growth is most rapid in infancy. Salzmann[2] points out that the child's weight increases from 3.3 to IO Kgms. in the first year, but the increase from IO to 30 Kgms. takes 7 years.

Growth and Function.

Normal Function is necessary for the continued growth of all our organs, after early normal differentiative growth. Growth is also influenced by

Heredity

Environment

Seasonal variations

Nutrition

General Physical Health.

Salzmann divides growth into two categories

(a) Somatogenetic

Growth in volume of the soft tissues. This is controlled by the "target" glands - Thyroid, adrenals and gonads.

(b) Morphogenetic

Growth of skeletal structures and is controlled by the anterior lobe of the pituitary gland.

Development relates to cell division, growth, differentiation, and maturation, and may be defined (Salzmann[1]) as the sequence of changes from cell fertilization to maturity. The higher the state of its differentiation, the earlier does the cell complete its growth e.g. nerve cells, adult erythrocytes, and cells on the outer layer of the skin. Conversely, connective tissue cells, and the basal cells of the skin grow and multiply for a longer period.

Differentiative Growth

(1) Morphologic changes in shape due to variations in the rate of growth in different directions,

(2) Histologic change in substance and structures of the cells

themselves, making tissues distinguishable from one another.

Maturation is believed to be initiated, and in part maintained, by the hormones produced by the anterior lobe of the pituitary gland, and the gonadal hormones.

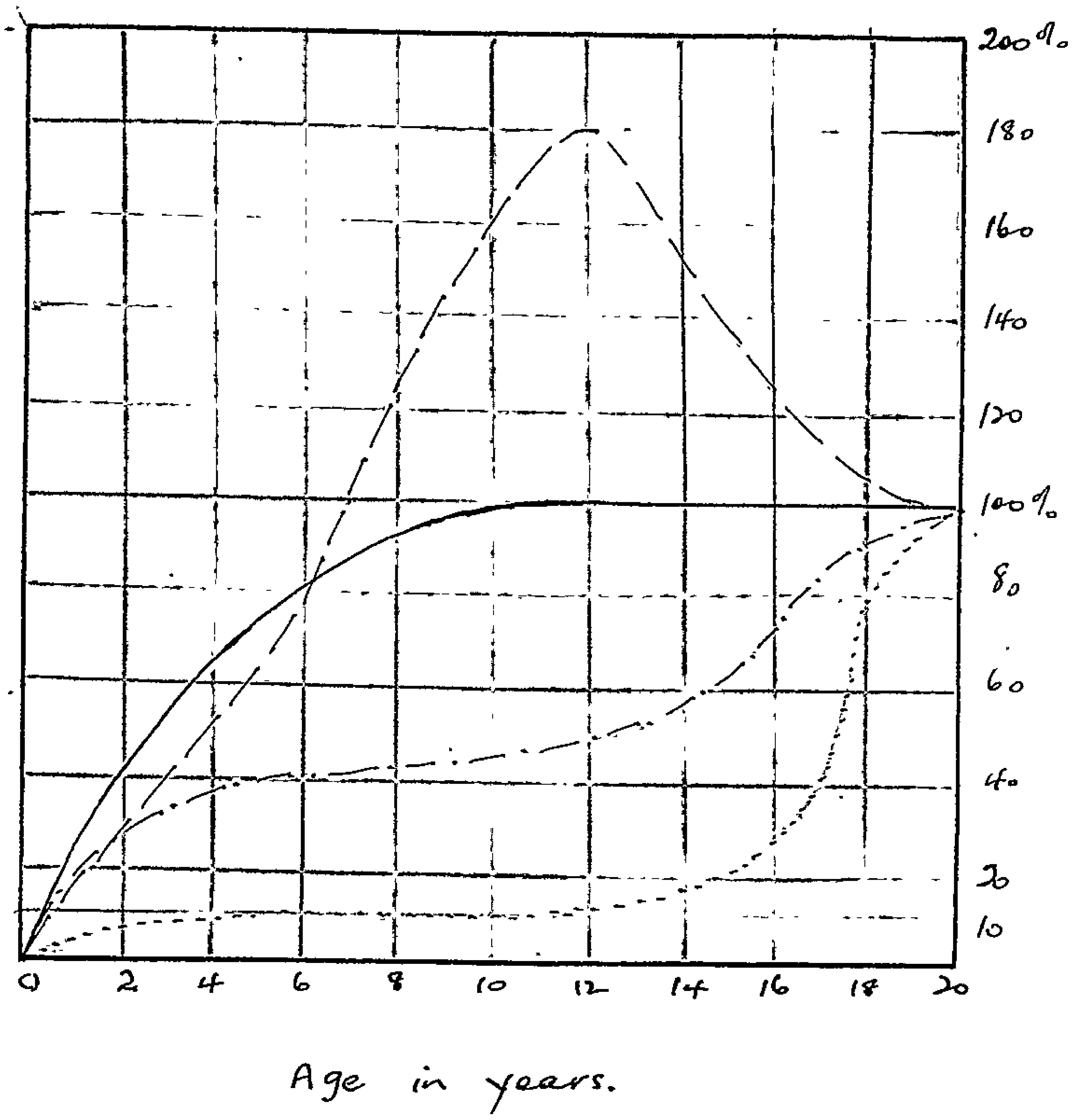
A method of separating and evaluating Growth and Development is by means of Wetzel's Grid Technique, presented by N.C.Wetzel[3].

Krogman[4] describes the general vertebrate plan of structure - a longitudinal primary axis, with cephalic and caudal ends, and two secondary axes - a dorso-ventral and a lateral. All are mutually at right-angles, so that growth is in three planes. Growth in bulk is achieved in all three directions, but developmental growth is differential or proportional.

In the growth and development of the child there are "lean" (spring-up) years and "fat" (fill-out) years. Krogman presents a table showing the conclusions of eight different researchers on the Periodicity of Human Growth. An example is that of Stratz

Suckling	Neutral children $1\frac{1}{2}$ - 7 yrs.		Bi-sexual child 7 - 15 yrs		Puberty. 15 years
	1st fill-out	1st stretch	2nd fill-out	2nd stretch	
Birth - $1\frac{1}{2}$ yrs	$1\frac{1}{2}$ - 4 yrs.	4 - 7 yrs.	7 - 10 yrs.	10-15 yrs.	to Maturity.

Scammon[5] presented a graph showing the major types of post-natal growth of the various parts and organs of the body.



Lymphoid Type Thymus, Lymph Nodes, Intestinal Lymphoid masses.

Neural Type Brain & its parts, Dura, Spinal cord, Optic Apparatus, many head dimensions.

General Type Body as a whole. External dimensions (except head & neck). Respiratory & Digestive Organs. Kidney, Aorta, & Pulmonary Trunks. Spleen, Musculature as a whole. Skeleton as a whole. Blood Volume.

Genital Type. Testis, Ovary, Epididymis, Uterine tube.

Krogman feels that Heredity in Dento-Facial relationships present a difficult problem. Shulz[6] in 1925 suggested that in evolution, the size of teeth and dental arches have decreased disproportionately. Ruprecht[7] (1939) felt that the shape and size of the jaws are in great measure determined by "heredity". Leroy Johnson[8] (1927) observed "The independence in genetic constitution of the maxillary structures from the mandible, and the independence of the teeth from both, is clearly demonstrated" .

Krogman points out the tremendous rate of increase in the size of the skull, by generalised growth. Adult

at birth, 39% of adult facial height, 57% of adult facial width has been achieved

at 5 yrs. 78% of adult facial height, 85% of width, 82% of depth has been achieved.

However there is a slower rate of change in proportion by localised growth (development).

Facial growth is Neural growth. It belongs to the head, even though cranial growth has a greater velocity, and terminates earlier than facial growth.

Brader[9] has written an interesting historical review of Research into Growth and Development prior to cephalometrics. There were three principal methods of attack :.

1. Histologic studies

2. Animal experiments - including vital staining, metallic implants and transplantation

3. Anthropologic studies

(1) Histologic Approach

In 1845 Goodsir examined osseous tissue microscopically and suggested that the cell was the important unit of bone growth. Tomes and de Morgan in 1853 recognised that cells were involved in resorption of osseous tissue. Kollicker in 1972 recognised osteoclasts and osteoblasts.

In 1892 Wolff's "Law of Bone Transformation" became known. He experimentally distorted osseous tissue and subsequently examined the spongiosa. He stated "Every change in the form and function of bones, or of their function alone, is followed by certain definite changes in their internal architecture, and equally definite secondary alterations in their external conformation in accordance with mathematical laws". The orthodontists using expansion techniques felt that bone would grow to accommodate the increased arches. However as Brodie[10] said "Wolff only mentioned change in form as a result of change of function. He said nothing about increase in size as a result of increase in function".

In 1904, Sandstedt discovered that bone resorption occurred on the pressure side during tooth movement.

In 1911 Oppenheim studied tooth movement (on monkeys). He noted that excessive forces eventuated pathology and hindered tooth movements.

In 1925 Benninghoff examined the compacta of bone, and offered substantiation of Wolff's observations on the SPONGIOSA.

(2) The Approach Through Animal Experiments

Belchier used madder feeding in 1736. In 1771 Hunter gave the first clear description of the growth changes in the mandible. Humphrey confirmed the method of ramus growth in 1864 using " ring experiments".

Brash published "The Growth of the Jaws and Palate" in 1924, and concluded that "the growth of the face is a complicated combination of surface and sutural growth". He felt that there is a delicate balance in the growth of bone - a balance between deposition and absorption according to the functional demands made on it.

Brader feels that, prior to 1930, neither the hereditary or functional effects were given precedence of importance in determining final morphology.

(3) The Anthropologic Approach

The earliest explanations of natural phenomena were theological, then later METAPHYSICAL.

In 1824 and 1830, St.Hilaire supported the growing evolutionary theory. Gregor Mendel produced experimental evidence concerning natural laws of Heredity. In 1859, Erasmus Darwin published the Origin of Species - a theory of the actual mode and process of evolution - that species had evolved from simple forms by inheritance of the effects of use and disuse. This report led to studies on comparative anatomy and paleontology.

Hellman[11] wrote in 1915 "Maloccluded teeth themselves are but diagnostic landmarks due to malformation of the jawbones". In 1919, he[12] concluded that there was

(1) Absence of correlation between tooth size and arch form.

(2) Remarkable variations in individual arch forms, which he attributed to evolutionary processes.

(3) Hereditary importance in the number, form, position, and occlusion of the teeth.

In 1928, Todd published "The Anatomy of Growth". He pieced together much of the knowledge of growth at that time. He suggested the practicability of accurate measurements from radiograms.

Development of Bones

Weinmann and Sicher[13] describe types of bone development.

(1) Those which replace a temporary cartilaginous part (Primordial or Primary cartilage) e.g. bones of skeleton. In skull ethmoid, inferior concha, bones at cranial base, pterygoid plate except medial.

(2) Those which develop in connective tissue - remainder of skull bones except mandible.

(3) Those without a cartilaginous predecessor, where, during their formation and growth, cartilage is differentiated from connective tissue, and then plays an important part in the growth of this type of bone (secondary cartilage) e.g. Mandible, and possibly clavicle.

Membranous Development of Bone

The bone develops in a condensation of the embryonic mesenchyme. Ossification begins at "centres". When two adjacent bones of the skull come into close relation, a suture develops between them.

Growth of Membranous Bones

A membranous skull bone may grow on the free surfaces or at the sutures. The site of apposition and resorption on the free surfaces and the extent of this varies in the different bones of the skull depends mostly on the age of the individual.

Sutural Growth is appositional growth on the opposing sutural surfaces, and is initiated by a proliferation of the sutural connective tissue.

Histologic structure of the sutural tissue reveals its double function of

(a) Firmly uniting the two neighbouring bones and

(b) Providing the site of proliferation for the "spreading" of the suture. It consists of three layers

Peripheral layers, adjacent to the bone, consist of dense connective tissue, the fibres of which are parallel to each other, and at right angles to the sutural surfaces of the bones. They continue into the bones as Sharpey's Fibres.

Central Layer

An irregular feltwork of connective tissue fibres, partly collagenous, partly precollagenous. This central layer is rich in cells, and is the site of cell proliferation and new formation and rearrangement of fibres. As sutural growth ceases, the central layer gradually disappears.

Secondary Cartilaginous Growth Centres :

The mandible develops as a membranous bone, lateral to, at some distance from, Meckel's Cartilage.

In the 3rd month of intra-uterine life, the connective tissue covering the bony condyloid process differentiates into cartilage, but only in the deep layers. Growth of the condyloid process proceeds by simultaneous growth of the cartilage, and its replacement by bone in the deep layers.

At the end of the growth period, there is a terminal bony plate, then a thin remnant of cartilage which persists throughout life. This cartilaginous cap is covered by a layer of dense connective tissue, which forms the articular surface.

During the development of the mandible, similar but less important centres of cartilage develop at the tip of the coronoid process and later at the symphysis. These centres have both disappeared at age of one year.

Weimann and Sicher then compare Cartilaginous Growth V. Bone Growth.

Bones grow by

(a) Bone growth (surface apposition)

(b) Cartilage growth

For examples (1) Enlargement of cranium as a unit by

(i) Cartilaginous growth

(ii) Sutural Growth

(iii) Surface apposition of bone

(iv) Modeling resorption.

(2) In MANDIBLE we see

(i) Cartilaginous growth at condyle

(ii) Appositional growth

(iii) Modeling resoprtion

Weinmann and Sicher state that if cartilaginous growth dominates appositional growth, we see a tall slender individual with a long face,- mandible long, ramus high and narrow, mandibular angle obtuse.

If surface apposition dominates cartilaginous growth, we see short and stocky individuals with short face - Mandible short, ramus low and wide, mandibular angle approaching a right angle.

When studying the growth and development of the face all the component parts of the head must be considered. This presents a four-dimensional problem - height, width, depth, and time. The lateral cephalometric radiogram offers an ideal medium for studying three of these, height, depth, time.

Camper, (1786) was one of the first to measure the relationship of the face to the head. Flower developed this work and devised the "Gnathic Index" which gave an idea of prognathism. The next basic advancement came in 1884 with the adoption of the Frankfort Horizontal Plane. Simon considered it necessary to relate the teeth to the cranium in 3 dimensions of space, and used 3 planes (i) vertical (ii) lateral (iii) Antero-posterior. He called his system Gnathostacics and also used Photostatic photographs.

Milo Hellman also computed standards of facial development based on measurements taken of normal cases.

In 1937 Broadbent [14] presented his paper "The Face of the Normal Child". He said "The face, in its internal form and structure, contains in a chronological sequence a detailed record of the individuals developmental growth progress from birth to maturity". Until circa 1922 the skulls of dead children were used for measurements and study of growth and development. Todd, Keith, Noyes, Hellman all studied the skulls of dead children in measuring growth and development. Todd[15] (1931) warned that the measure of dead skulls is largely a measure of <u>defective</u> growth, and to measure <u>normal</u> growth, we must measure healthy, living, children.

Broadbent realised the value of superimposing facial X-rays on base lines found by connecting such points as Sella Turcica, Nasion, ear-hole, and eye-point. He designed the roentgenographic craniostat in 1931,[16] which provided a standardised technique, and enabled accurate measurements of the living head. Improvements in design produced the cephalometer, which permitted the production of a complementary pair of standardised radiograms, one in the frontal plane, one in the saggital. These permitted 3 - dimensional measurements of internal and external landmarks useful in measuring developmental growth of teeth and jaws, and orthodontic changes therein. This roentgenographic technique does not depend upon measurements taken through soft tissues of unknown thickness. Investigation proved that neither ear nor eyepoint was a stable landmark, and landmarks in the base of the skull are used. Broadbent used the Bolton-Nasion plane and used its registration point "R" in the sphenoidal area for registering tracings of subsequent pictures of the same individual and of different individuals. Broadbent's paper[14] and that of Brodie[18] in 1941 were of great significance. They advanced markedly the knowledge of growth and development, and have exerted great influence on orthodontic treatment methods of the last two decades. Until then it was generally believed that facial proportions changed during growth, and also that there were periods of accelerated growth. Hellmann undertook serial studies of living subjects, using anthropometric measurements. His findings indicated changes in facial proportions in the course of growth, and he reported spurts in late infancy and preceding puberty.

Goldstein (1936) and Davenport (1940) found changes in proportion and an adolescent spurt. Todd (1932) stated "Developmental Growth implies modifications of proportion and constant readjustment of parts as well as local modifications". Krogman (1930) measuring dried skulls, compared the growth of anthropoids to that of man. He too reported changes in facial proportion.

Broadbent [14] undertook long range investigations of large groups of growing children, by superpositioning tracings of serial headplates. He made no mention of acceleration of growth rate.

Brodie [18] studied normal developmental growth from the third month to the eighth year. He used cephalometric radiograms, and studied each facial component individually. He used the anterior cranial base plane (S-N) for orientation, and his study indicated that the facial pattern was established early in life, and tended to remain constant throughout growth. Brodie was the first investigator to indicate definitely the constant proportionality of the face. Ortiz for his Masters thesis at the University of Illinois subsequently studied the growth of the head from birth to three months.

Brodie's[20] work indicated that the anterior and posterior cranial bases were independent variables. These variations were shown to be major aetiological factors in Class II Div.I malocclusions, responsible for differences in the antero-posterior position of the temperomandibular fossa.

Applebaum[21] endeavoured to integrate two different methods of study of the growth of the head

(1) That employed by anatomists - studies of histological sections of foetal material, and animal experiments.

(2) That employed by Broadbent - superimposing X-ray films on a relatively fixed plane of reference.

He points out that the histologist has a limited view in space and time of isolated sections. Although histological technique permits understanding of local growth changes in teeth and jaws, the histologist can be misled in interpreting the growth of the jaws and teeth in relation to the cranium.

Tirk[22] investigated the growth of areas during the growth period, as contrasted to linear measurements.

He appraised the growth of the

Nasal

Oral

Total Facial

Cranial Areas.

These areas were measured on successive tracings of cephalometric headplates, using a Polar Planimeter (an instrument which measures areas enclosed by irregular perimeters). He found that

(1) The three facial areas exhibited constant proportionality throughout the growth period, indicating the early delineation of a definite pattern of proportional growth.

(2) Cranial and facial growth occurred at different rates. Plotting intra-facial growth increments against each other produced straight lines.

Plotting cranial increments against facial increments produced curves. These curves were the result of early slowing of the cranial rate, and the maintenance of a relatively more rapid facial rate over a longer period of time.

Brodie[20] stated that the face, from birth, must increase in size at 6 - 8 times the velocity of that of the cranium.

(3) Tirk found that this series indicated an adolescent acceleration in the growth rate of all areas studied, otherwise the growth rate was smooth and progressively diminishing.

Embryology of the Face and Oral Cavity.

Orban[23] points out that knowledge of the embryology of an organ is essential to understand its structure, and malformations when they occur.

The first significant development of the face occurs at the 3rd week of intra - uterine life, when the frontal process, constituting the middle part of the upper face, forms as a broad prominence between the two maxillary processes. At the fourth week, oval grooves (olfactory pits) divide the frontal process into a medial and two smaller lateral nasal processes. The lateral nasal processes are adjacent to the maxillary processes, being separated from them by the nasomaxillary groove.

The medial nasal process grows downwards more rapidly than the lateral nasal processes. Its inferolateral corners are rounded and prominent (globular processes) and contact the maxillary processes.

Orban points out that it is very important in explaining and understanding malformation to realise that fusion of primarily separated "processes" occurs only during formation of the primary palate and to some extent during the development of the mandible. In all other regions, the grooves separating the facial processes gradually become shallower by proliferation of the mesoderm, and finally disappear.

Formation of Primary Palate begins with a deepening of the nasal groove or olfactory pit. Here the median nasal process first fuses with the adjacent part of the maxillary process (6th week) . Later the median nasal process fuses with the tips of the lateral nasal processes. The posterior extension of this epithelial wall is called the bucconasal membrane and this ruptures at the 7th - 8th week to form the primary choana, connecting the nasal groove to the oral cavity.

The bar of tissue between the nasal duct and the oral cavity is the primary palate.

Development of Mandibular Arch

At first an undivided arch, a-t four weeks furrows appear on the mandible. One central furrow divides the mandible in halves, two parallel lateral.furrows.

These grooves close at 6 - 7 weeks, simultaneously with the fusion of the nasal and maxillary processes.

At first the mandible is small compared with the maxilla. At about 12 weeks the mandible catches up with the maxilla, then lags behind again.

The oral opening is at first very wide. In the lateral area, the upper and lower lips fuse to form the lips, and thus reduce the width of the mouth.

Development of the Secondary Palate.

The primary palate develops into the upper lip, the anterior part of the alveolar process, and the premaxillary part of the palate.

The secondary palate, which separates oral and nasal cavities, is formed by a fusion of the palatine processes. The anterior parts of the palatine processes fuse with other, and also with the inferior edge of the nasal septum to form the hard palate. The posterior parts of the palatine processes fuse to form the soft palate and uvula (12th week).

The fusion of the palatine processes can only occur when the tongue moves down, and evacuates the space between these processes. This is permitted by the sudden growth of the mandibular arch in length and width at this time (11th week). The tongue drops down and the growth of the palatine processes alters to a horizontal direction until they meet in the midline.

Growth of Skeleton of Upper Face.

Salzmann[1] points out that the Maxilla originates in two parts - the premaxilla and maxilla proper. Each begins to ossify at the sixth intra - uterine week. Formation of the maxillary alveolar process begins in the fourth foetal month and is completed when the 3rd molars have erupted.

Strang[24] states that the central problem during growth is the shift and enlargement of the maxillary complex i.e. maxilla and palatine bone.

The important growth sites are three sutures on each side

(1) Fronto-maxillary suture

(2) Zygomatico-maxillary suture (and secondarily the zygomatico-temporal suture

(3) Pterygo-palatine suture (between pterygoid process of sphenoid bone and pyramidal process of palatine bone)

(a) All the sutures are parallel.

(b) All are directed downward and anteriorly.

Therefore growth in these sutures has the effect of "shifting" the maxillary complex downward and anteriorly.

Salzmann[1] states that the pterygoid process descends about 15mms. during growth.

Growth in these sutures increases vertical and antero-posterior dimensions of the nasal parts of the maxillae and palatine bones only. As the maxilla grows downward, the antrum replaces the erupting deciduous and permanent teeth which originally were located beneath the lower border of the orbit.

The subnasal part of the maxilla increases in height by apposition of bone on the free borders of the alveolar process, simultaneously with the eruption of the teeth.

IN AVERAGE SKULL

Sutural growth contributes more to the forward shift.

Alveolar growth contributes more to downward shift. At the same time, regulatory bone apposition and modeling resorption take place

e.g. (a) Appositional growth on orbital floor, resorption on nasal floor, prevent excessive height of orbits from growth at sutures.

Salzmann[1] states that the circumference of the orbit becomes relatively stationary after four years of age.

(b) Resorption of nasal floor is accompanied by apposition on oral surface of palate. Thus palate "shifts" downwards by additive effect of sutural growth, and continued rebuilding. The apposition of bone on the orbital floor is also a proof of the reality of sutural growth.

(c) Intense apposition of bone at the free border of the alveolar process translates the flat curve of the infantile palate to the more highly arched curve of the adult palate. There is a total growth increase in height of about 10 mms.

(d) Growth in width is achieved by

(i) surface additions to the body and alveolar process, accompanied by absorptions on the lingual side of the alveolar process and on the lateral walls of the nasal passages and in the antrum.

(ii) Active growth centres in the median palatine suture increase the width of the palate. At four years of age, five-sixths of the mature palatal width is attained and adult width is attained by IO years. Lewis[25] found that the deciduous arches increased in width to accommodate the permanent teeth, and that the greatest increase in inter-canine width occurs between 6-8 years of age. Salzmann[1] (book) quotes Channing and Whistler as finding no increase in inter-canine width after the eighth year, and probably not after the eruption of the first permanent molars. They also found that the adult width at the first permanent molars is attained by the tenth year. However Hellman (quoted by Salzmann) concluded that maximum inter-canine breadth is not attained until about 12 years of age, and is independent of increase of palatal width.

Because of this lack of agreement, and from my own observations, I feel that in the treatment of malocclusions where deficiency is a factor it is wiser to observe the case for a period, watching for a favourable growth trend, than to assume that inter-canine growth is completed by, say, 8 years of age.

Salzmann says that the maxilla depends upon correct nasal breathing and adequate blood supply for its normal growth, rather than normal function. He points out that the maxilla may be of normal development in cases of early mandibular ankylosis. The premaxilla, derived from the frontal process, is one of the four main growth centres of the maxilla. Situated at the anterior end of the palate, it carries the incisors. Its suture with maxilla disappears in the first year of life.

At birth, the maxilla is proportionately broader than, but not as high as, the adult bone. The undeveloped alveolar process lies almost in the same plane as the palate. The alveolar process grows outward, downward, and forward, by surface appositional growth. Growth occurs here in the first six months of life before the deciduous incisors erupt, and continues as the teeth erupt.

The length of the palate is more than doubled during the growth period : the increase in breadth is much less. Increase in length is attained by

(i) Additions to the posterior border of the palatal bone

(ii) Growth at the transverse palato-maxillary suture

(iii) Growth at the premaxillo-maxillary suture in early post-natal life,

(iv) Apposition to the anterior surface of the maxilla.

Moore[26] studied the head growth of a Macaque rhesus monkey with a dental age corresponding to that of a 5 year old human, by vital staining, then embedding in acrylic monomer, then sectioning with a lathe, while undecalcified. He found that the sutures were the sites of growth in the maxillary complex, accompanied by growth of the alveolar processes.

Gans and Sarnat[27] studied the growth at the frontomaxillary, frontozygomatic, zygomatico-temporal, zygomaticomaxillary,and premaxillomaxillary sutures of growing Macara rhesus monkeys. The method used was to place metallic implants on each side of the suture. Direct measurements were made between each pair of implants at the time of placement and upon completion of study (7-10 months later). to record total growth. Monthly cephalometric radiograms were also taken to record the rate of growth.

From the direct measurements they found that the greatest growth was at the zygomatico-temporal suture, then the zygomaticomaxillary suture. Growth was slight or non-existent at the other sutures. Appositional growth was most pronounced on the zygomatic arch.

From the X-rays they found that the anteroposterior growth was most active in the 8-15 months age group. Vertical growth was most active in the 18-34 months age group.

All implants moved in a downward and forward direction except those on the temporal side of the zygomaticotemporal suture, which moved down and backwards.

They also found that outlines of the floor of the nose and the occlusal plane descended in a plane parallel to each other.

Scott[28] states that a growing facial suture is composed of five layers between the bony margins of the suture.

(1) A cellular layer belonging to each bony unit

(2) A fibrous layer continuous with the fibrous periosteum covering each bone

(3) A central layer containing blood vessels and uniting strands of collagenous fibres.

Growth takes place at the cellular layers. The bones at the suture may be edge-to-edge or overlapping. With edge-to-edge relationship, growth at the suture is accompanied by separation of the bones involved. The process may or may not involve a change in the position of the suture depending upon whether growth takes place at the sutural surface of both bones, or only one.

In overlapping sutures, growth can occur without the bones separating. With surface deposition, one bone migrates over the surface of the other, and the position as seen from the surface changes (e.g. fronto-nasal suture) consequently, Scott points out that care must be taken when using sutures as "fixed points" for superimposition purposes.

Scott makes the point that growth at the sutures does not in itself produce separation of the bones at the suture - this is due to growth of other organs such as the cartilage of the chondrocranial and chondrofacial skeleton, the brain, the tongue etc., Scott states that the maxilla is held between the vertical plate of the palatine bone, and the zygomatic bone, as between two hands. Growth of the cartilage of the nasal septum moves the maxilla downward and forward between them, and growth takes place at the frontomaxillary suture as long as this movement is taking place.

Growth of the Mandible.

The main growth centre is the hyaline cartilage of the condyle. At Birth, mandible consists of two halves, separated in the midline by the symphyseal cartilage and the connective tissue in which the mental bones develop. This suture-like junction is not, according to Weinmann and Sicher, a site of post-natal growth.

The mandible develops as a membrane bone. Ossification begins in the membranous tissue lateral to Meckel's cartilage at about the fortieth day of foetal life. Secondary centres of hyaline cartilege develop in the growing bone. The coronoid process and the condyle appear about the fifty-fifth day. By the middle of the 3rd month, the mandible assumes its characteristic shape. The mandible develops as two symmetrical halves, each having six centres of ossification. The halves unite during the first year of life. Salzmann points out that the mandible develops and replaces Meckel's cartilage, and is not formed from or within this cartilage.At birth, the rami are short, and the condyles poorly developed. The body is full of tooth buds, and the alveolar process not yet formed.

The secondary cartilage at the tip of the coronoid process disappears before birth, but that at the tip of the condyle persists. Growth here occurs by proliferation of the cartilage, and its gradual replacement by bone. This hyaline cartilage is covered by a dense layer of connective tissue, which enables the cartilage to increase by appositional growth (unlike the articular cartilage of long bones, which has no connective tissue covering, and in long bones, the cartilage, both epiphyseal and articular, thickens by interstitial growth).

Thus the hyaline cartilage of the condyle is unique, and differs widely from that of other cartilaginous growth centres in its reaction to certain pathological conditions.

Normal growth of the mandible occurs by

(1) Condylar growth increases the over-all length of the mandible

(2) Appositional growth along the posterior border of the ramus adjusts the width of the ramus and the length of the body to the growing height of the ramus.

(3) Appositional growth at the tip of the coronoid process keeps pace with the increase in height of the ramus

(4) Absorption of the anterior border of the coronoid process and ramus corrects the antero - posterior dimension of the ramus, and lengthens the alveolar space distally.

(5) The height of the body increases by apposition at the alveolar border.

(6) Growth at condyle causes downward and forward shift of mandible (as condyle rests against the articular fossa at the cranial base). This shift is accentuated, in the first two years of life, by the changes in the OTIC region of the temporal bone.

(7) Apposition of bone at lower border of the mandible, and in region of chin, reinforces and models the lower jaw.

(8) Serial roentgenograms (Brodie[18]) have shown that the gonial angle does not change during growth. However the condylar angle (the anthropological "mandibular angle") decreases during the growth period. This is due to a change in the direction of the proliferation of the condylar cartilage. In the first years of life, the direction of proliferation is inclined more than in later years. In the first phase of growth during which the length of the dental arch increases rapidly, the mandible grows more in length than in height.

In the second period of growth, the face continues to grow in height after the length of the dental arch has been established. This pattern of growth results in the gradual diminishing of the condylar a-ngle, that is extremely obtuse at birth and in infancy.

After the loss of all teeth, especially if dentures are not worn, the condylar angle increases again - disuse atrophy.

(9) Since the two halves of the mandible diverge posteriorly,

antero - post growth necessarily increases the transverse diameter, or intercondylar distance.

Weinmann and Sicher,[13] state that growth in width occurs as a result of surface additions to the lateral surfaces of the body, alveolar process and rami, with compensating resorption on medial surfaces. However Brodie [18] found that, with alizarination, the mandible was heavily stained on all surfaces up till 6 years. Then growth "sites" appeared. Deposition along inferior border ceases and only faint staining persists on the lateral surfaces, and ceases there later.

The Glenoid Fossa grows slowly downward and backward, consequently the antero - posterior growth of the mandible has to be in excess of that of maxilla to produce a net downward and forward growth.

Salzmann[1] states that the mandible does not depend upon the presence of teeth for its development, but fails to develop in cases of early ankylosis - indicating that muscular function and its associated increase in collateral blood circulation are mainly responsible for mandibular development.

Growth and Development of muscles (Salzmann)

Voluntary muscle grows in early foetal life by increase in number and size of the fibres. In post-natal life, growth is mainly by hypertrophy.

Muscle tissue consists of long nucleated fibres, each with its own nerve supply, covered by sarcolemma. The fibres are bound into bundles whose coverings fuse with the outer sheath of the muscle to form the tendons, which afford the origin and insertion of the muscles to a bone, the skin, or another muscle. The capillary system nourishes the muscles, which serve as a storehouse for carbohydrates and proteins.

The facial muscles are inserted in the upper and lower lips, and contribute to the balance of the dental arches, but do not affect the relationship of the face to the cranium. Habits involving the facial muscles may be due to nervous instability, imitation, or pleasurable effects. These habits disturb muscular balance, and may result in dentofacial abnormality.

The muscles of mastication (internal and external pterygoids, masseter, and temporal muscles) arise from the mesoderm of the mandibular arch.

Normal muscle function was found by Rogers[29] to be a factor in determining the sta bility of facial form and occlusion after orthodontic treatment. Salzmann states that muscle function plays an important part in assisting or interfering with the attainment of the growth pattern inherent in the individual. Vigorous mastication, resulting in well developed musculature, will nearly always lead to well-developed jaws and faces. Waugh investigated the Eskimos and found powerful muscles and well-developed jaws due to their hard,fibrous,resistant diet.

Muscular pressure and the inclined planes of the teeth are influential in maintaining effective and normal occlusal relations of the teeth and jaws of the growing child. Masticatory stresses on mandibular molars promotes forward translation of the dental arch. The meeting of the two component forces of the maxillary and mandibular jaws in occlusion produces an anterior resultant force which aids in

(1) The forward growth of the denture

(2) Lateral growth of the denture

(3) Maintains proximal contacts.

The Tongue is important in mastication, deglutition and speech. It is agile and powerful and feeds the masticatory machine.

Scott[30] summarises what is known about the growth and development of muscle, and studies the relation of the muscles of mastication to the growth and development of the facial skeleton and of the dentition.

Areas of degeneration in a developing muscle may be associated with nezve lesions, as muscles do not fully develop without their nerve supply.

Growth in length of the muscles of nastication is related to the growth of the 2 cartilaginous areas in the skull.

In the case of the

Masseter

Internal Pterygoid

Vertical fibres of Temporal

the cartilage of the mandibular condyle continues to separate the muscle origins from insertions.

In the case of

External Pterygoid

Horizontal fibres of Temporal origin and insertion are separated by the cartilage of the cranial base (spheno-occipital Sychondrosis).

Space is also provided for the muscles of mastication by the lateral growth of the zygomatic arches.

Growth of bone (i.e. the absolute size attained) is largely independent of function. However the degree of function and muscle development influences the thickness of the cortical layer, and the internal architecture, of the bone.

<u>Growing</u> bone is susceptible to <u>deformation</u> from continuous abnormal forces. If the structure of the bone is itself abnormal (e.g. in rickets or Paget's disease) then normal forces will produce abnormalities of bone form, again chiefly at centres of most active growth.

Scott points out that the Eskimos' muscles of mastication are developed to a greater degree than most human races, and lists the characteristic features of their skull

(1) Marked temporal ridges

(2) Highly developed zygomatic arches for

(a) Strong Masseter muscles

(b) To allow space for the large temporal muscles

(3) Lateral pterygoid plates are wide and maxillary tuberosities well-developed ,

(4) The mandible, angular region and coronoid processes well developed. Bicondylar width wide,

(5) Glenoid fossa shallow, articular eminences comparatively flat

(6) Well-developed palatal and mandibular tori frequently observed.

Several writers have mentioned muscular exercises with the object of

(i) Assisting in the development of normal occlusion a d alveolar growth

(ii) Prevention of malocclusions due to perverse muscle forces

(iii) To assist in the corrective treatment of certain malocclusions

(iv) To assist during the retention period.

Rogers [29] was the pioneer worker in this field and he proposed corrective exercises to develop muscular tonicity and establish correct muscular function. Lischer later proposed the term "myofunctional therapy".

The principles Rogers followed were to first correct the malocclusion orthodontically and institute corrective muscle exercises. He ensured that the child's nutrition and endocrine function were checked, and carefully ascertained the presence of any abnormal habits while eating, sleeping,playing etc,. He felt that as a result of myofunctional therapy, facial development is enhanced, masticatory efficiency improved, and the retention period shortened.

Specific Muscle Exercises.

(1) Pterygoid Muscle Exercises.

Rogers feels that inherent weakness of the pterygoids is often responsible for distal position of the mandible, and recommends this exercise when a tendency to distoclusion is noticed in a young child.

The mandible is brought forward till the incisors are placed anterior to the maxillary incisors (provided the maxillary incisors are in their normal position). The pterygoids are then relaxed till the mandible is in the position where the dental arches are in their relatively correct mesiodistal relationship. General added tonicity and muscular control will be gained from this exercise.

(2) Masseter Temporal Exercise.

Rogers recommends this for developmental and retention benefits, and feels they are of benefit at some stage of the treatment of all forms of malocclusion. The internal pterygoids are also involved here.

The mandible must be placed in its correct position (may be assisted by an inclined plane), and the muscles are contracted and relaxed. The patient places a fingertip over the masseter muscle near the angle of the mandible to feel the contracting and relaxing movements.

Rogers claims that it is possible to develop either the maxillary or mandibular arch with skilful use of this exercise.

(3) Tongue Exercise.

Used as an adjunct to the masseter - temporal exercise, this exercise trains the tongue, and strengthens those muscles influencing mandibular arch development.

The tip of the tongue is placed against the mucous membrane below the mandibular incisor teeth. With each masseter - temporal contraction, the tongue is pressed forward & in automatically widening, it is forced against the lateral sides of the alveolar process, thus preventing narrowing of the mandibular arch. The child's finger is held under the chin to feel the movements of the submandibular muscles.

(4) Mentalis Muscle

Johnson recommends Myofunctional therapy of this muscle, and feels that it assists development of orbicularis oris and associated muscles Overdevelopment of mentalis is frequently seen in maxillary protrusions. The upper lip does not do its share in closing the lips and tautness of the mentalis and dimpling of chin is seen when lips are closed.

The exercises are

(i) Upper lip development exercise

(ii) Forcibly enunciating letter "P"

(iii) Whistling.

(5) Orbicularis Oris - Facial Muscle Exercises.

Establish tonicity of these muscles, improving facial contours and assisting correction and retention. An exerciser, devised by Rogers, is used for this exercise and photographs which he presents demonstrate a marked improvement.

(6) Passive Swallowing exercise

This exercise is described by Strang (24), and is used to train the muscles involved in swallowing to work smoothly and without perverted contractions and to correct tongue-thrusting spasm.

(7) General Tonic Exercise

For general development of facial musculature. A mouthful of warm saline is forced back and forth between the teeth with the teeth firmly in occlusion. Strang[24] points out that at birth and up to the time of eruption of deciduous teeth the maxillae and mandible are completely filled with developing teeth. The only sign of maxillary sinuses are slight infoldings of the nasal mucous membrane. opposite to the germ of the second deciduous molar. The body of the mandible is small, with little vertical growth. The mandibular canal lies close to the lower border of the bone, the crypt of the second deciduous molar is located at the junction of body and ramus.

When the deciduous teeth begin to erupt,alveolar bone formation occurs. As the teeth leave the body of each maxilla, the antrum grows by resorption into a pyramidal cavity in the body of the maxilla. The base is formed by the lateral wall of the nasal cavity, and the apex by the zyomatic process. The zygomatic arch grows by lateral addition and medial resorption. The malar process is at first adjacent to the second deciduous molar region. As the maxilla grows forward, it is eventually found opposite to the first or second permanent molar.

Brodie[20] found that, at birth, the upper incisors are well behind a line dropped from ANS. From here back, the teeth lie at progressively higher levels with E at or above the level of the nasal floor, and 6 posterior to E and still higher, just anterior to the Pterygomaxillary fissure.

In the mandible, the gum pad of thick connective tissue occupies the place of the future alveolar process. Brodie found that the teeth lie in open crypts below the gum pad, closer to the free border and more nearly on the same level than those of the maxilla. The crowns of all the deciduous teeth have started to calcify, and frequently one cusp of the first permanent molar.

Brodie [20] breaks down the face into sections and studies their growth separately.

Growth of Nose.

Bounded above by the cribriform plate of the Ethmoid bone, anteriorly it is lengthened by the frontal bone, and posteriorly by the sphenoidal body. The length of the floor of the nose is determined by the anterior amd posterior nasal spines.

Growth

(1) S.N. slowly lengthens (a more forward position of N)

(2) The angle S.N.ANS remains constant, indicating that ANS is going forward at the same relative speed as N.

(3) The hard palate descends in parallel fashion

(4) The PNs goes straight downward.

(5) Pterygo-maxillary fissure travels straight downward.

The growth of this part of the face is steady and even, with the Posterior portion growing downward, and ANS downward and forward, Brodie found that the Nasal height (N to ANS) is 43% of Total face height (N to chin-point) regardless of age.

Broadbent [14] found slight differences in these movements

Nasion - Forward and slightly upwards.

P.Ns. - Downwards and slightly backwards.

He also describes the movements of other important skull features

Orbital - Forward and downward

Porion : Downward and backward

Bolton Point : Downward and backward

Gnathion : Downward and forward

Gonion : Down and slightly backward.

Broadbent found that with congenitally absent teeth there was a reduction in size of the facial mass, and an altered relation of the dental arches to their supporting bones, in proportion to the number of teeth that are missing. The presence of teeth is not necessary for normal growth of the jawbones, but it is necessary for growth of the alveolar processes.

Cohen and Garn [31] studied the facial growth of a patient with congenital Ectodermal Dysplasia, from the age of 34 months to 10 years. Although the patient only had a total of 10 teeth in the primary and permanent dentitions, they concluded that the absence of teeth had no effect on the growth of the jaws.

Weinmann and Sicher summarise that tooth development and eruption are dependent upon bone growth.

(1) The growth of the maxilla and mandible in an A/P direction provides the space for successive eruption of posterior teeth

(2) The growth of the jaws in height, initiated by the vertical growth of the ramus,is necessary for the free vertical eruption of the teeth

(3) Growth of bone tissue is one of the "forces" of eruption.

(1) At 3 years of age, the jaws are just long enough to accommodate the desiduous teeth. The first permanent molars are located in

(a) Root of ramus, occlusal surface facing upward and forward

(b) Maxillary tuberosity occlusal service facing downward and backwards. These teeth rotate into their proper positions. Brodie [20] found that ifalizarine is injected, there is always a heavy staining at the maxillary tuberosity. This structure is braced against the pterygoid process of the sphenoid bone - a cranial part. Brodie found that the pterygomaxillary fissure travels straight downwards, so that growth at the tuberosity results in a downward and forward movement of the maxilla. Frequently there is insufficient room for the 3rd molars. The loss of the third molars, and the reduction of facial prognathism are two phases in the phylogenesis of man. However the shortening of the jaws is further advanced than the shortening of the dental arch, and we frequently see impacted and imbedded third molars.

(2) Inhibition of vertical growth, as in mandibular retrusion, causes an under-eruption of posterior teeth. Conversely, in mandibular protrusion, where the ramus is too high the teeth are in supra-occlusion.

(3) Influence of bone tissue on eruption.

Eruption is the result of differential growth between the teeth and the surrounding bone.

Orban[23] describes three Phases

(1) Pre-eruptive

(2) Pre-functional

(3) Functional.

Pre-functional

Proliferation of the pulpal connective tissue generates the slight pressure for tooth movement. This pressure is directed occlusally because the growing root end rests on the hammock ligament.

Weinmann and Sicher[13] state that tilting, rotating, and bodily movements during eruption are due to the influence of surrounding tissue upon the tooth. Growth of bone, preceded by the growth of osteogenic connective tissue in distinct and limited areas exerts pressure on the teeth.

(1) Growth of bone at the fundus of the crypt accounts for an axial movement.

The large amount of fluid in the hammock ligament acts as an hydraulic cushion, distributing evenly the pressure of the growing bone on the growing root end.

(2) Apposition of bone in certain restricted areas is the primary moving force for tilting, rotating, and drifting movements of the erupting teeth. As long as the crown is imbedded in the jaw, and situated in a wide bony crypt, the connective tissue between the bone and the reduced enamel epithelium covering the crown is rich in fluid. This fluid renders the connective tissue incompressible, and thus pressure exerted by the growing bone is transmitted to the tooth. As the tooth moves, pressure on the bone in the direction of movement produces resorption.

The Eruption of the Teeth and Development of Occlusion.

Broadbent's [32] paper on the Ontogenetic Development of the Occlusion (1941) was an important contribution, presenting for the firsttime accurate data from healthy children. Brodie[20] (1942) presented information on the eruption of teeth. Sillman[33] presented a serial study of occlusion in 1948. Sheldon Friel [34] (1954) presented a very informative article on the development of ideal occlusion of gum pads and teeth.

Upper Incisors :

Brodie[20] found that the upper deciduous incisors, and their permanent successors, erupt along a straight line, and remain on this line, directed downward and forward, after occlusion is established. Friel [34] studied 369 radiographs of children 3 - 6 years of age. He found that in 85.7% of cases, upper laterals lay lingual to, and partly overlapped by, upper centrals. 14.3% showed either one or both laterals labial to the centrals and rotated. Friel is doubtful if in these latter cases, the incisors could erupt in good alignment. He feels that two processes result in room for the larger permanent incisors

(a) Bone Growth. An increase in size of the alveolar arch is evidenced by spacing of the deciduous incisors. Friel describes three types

(i) Root and Crown Spacing

(ii) Root spacing only

(iii) A combination of both types.

(b) The direction of eruption of incisors.

They move downwards and forwards, and thus the arc is larger. As the centrals erupt, they expose their narrow necks to the crowns of the laterals, which can thus escape from their partly - overlapped positions and move downwards and forwards.

Broadbent[32] points out that, in a normally developing dentition, the laterals may be markedly distally inclined during and after their eruption. This is due to pressure on the roots of the laterals by the crowns of the cuspids. Broadbent named this the " ugly duckling " stage. He also pointed out that (in normal dentitions) there may be a definite spacing between the centrals, which may persist until the cuspids erupt.

Eruption of Cuspids

Dewel[35] has pointed out that of all teeth the upper cuspid has

(1) Longest period of development

(2) Deepest area of development

(3) The most devious course to travel from point of origin to full occlusion and also that it develops in the most concentrated part of the denture, and occupies successively several different developmental positions from which it may be deflected from its developmental course.

As with all permanent teeth, the permanent cuspid germ branches off from the dental lamina that connects the deciduous cuspid bud to the oral epithelium. Thus the permanent germ is at first situated occlusally and somewhat lingually to the deciduous crown. As the deciduous cuspid erupts, and the alveolar process increases in height, the permanent cuspid germ shifts lingually until the deciduous cuspid passes it into the dental arch.

At 12 months, the cuspid crown is calcifying, and is positioned between the roots of the first deciduous molar. At $2\frac{1}{2}$ - 3 years, the cuspid is situated immediately above the first bicuspid, which is above the first deciduous molar.

From this point, the cuspid must migrate forward at a rate greater than the forward growth of the maxilla and of the deciduous teeth, to reach its final developmental position above the deciduous cuspid.

The cuspid succeeds a smaller tooth and, as it erupts, it wedges itself between teeth which are already established in occlusion. Delayed resorption of the deciduous cuspid root can cause deflection of the cuspid.

Eruption of Bicuspids.

Form lingual to and at the level of the occlusal plane of the deciduous molars. When the deciduous molars are in occlusion, the bicuspids are situated between the roots of the deciduous molars.

During eruption, the bicuspids tend to move distally, particularly the lowers. In normally-developing occlusion, this distal movement is prevented by contact with the first permanent molar. Radiograms of mandibular teeth frequently show resorption of the distal roots of the lower deciduous molars proceeding more rapidly than the mesial roots.

Eruption of Molars

The maxillary molars form in the tuberosity and are directed distally. As they erupt, they tilt forward. Brodie[20] found that they drop vertically until then occlude with the mandibular teeth, and then follow a downward and forward path parallel to the incisors. The first permanent molar is found on a line joining S to the chin-point. (However , later Brodie states that if the maxilla and mandible are dissociated from the cranium, and only the tooth - jaw relations are studied, it is seen that eruption is in an almost vertical direction").

The mandibular molars form in the base of the ramus, and are directed upwards, forward, and slightly lingually. Brodie describes that the mandible is growing in length by apposition to its posterior border, and at the same time the anterior margin of the ramus is resorbing at a slightly slower rate. Thus each succeeding molar is uncovered by the retreat of the anterior margin.

Elman measured the distance along a line parallel to the occlusal plane from the posterior border of the ramus to the last molar in occlusion (as soon as possible after occlusion with antagonist is established). He found that each succeeding molar erupted at the same distance from the posterior border.

Orban[23] points out how erupting teeth may cause resorption on the roots of the neighbouring teeth. This occurs frequently to the distal root of the lower second molar, from pressure due to the oblique position of the erupting 3rd molar. This also occurs to lateral incisor roots from pressure by cuspids.

Functional Phase of Eruption

Weinmann and Sicher[13] describe how eruption continues throughout life to compensate for occlusal and interproximal wear. Tooth movement is due to differential growth between the tooth and surrounding bone. Normally cementum grows throughout life by apposition to its entire surface. However the rate of cementum apposition varies in different areas and is greatest at the apical region of the tooth, thus lengthening the root and partly compensating for occlusal and incisal wear.

Alveolar bone grows in certain small areas throughout life. Apposition normally occurs at the alveolar fundus to compensate for occlusal wear, and on the distal surface of the alveolus to compensate for the forward movement of the tooth due to inter - proximal wear.

Development of Occlusion

Sillman[33] made serial casts of 50 children from birth to approximately eleven years of age. He studied the

(1) Predental Phase

(2) Change of dental arch

(3) Changes of Anatomy

(4) Changes of Morphology

(5) Changes of occlusion

He feels that one can achieve much in preventive orthodontics if one is trained to recognise the onset of the subtle departures from a "good" occlusion and then applies simple measures to prevent their disturbing influence during the developmental stages.

Sillman states that all the teeth normally erupt from the true gum pad region and if they erupt from the false gum pad region posterior to the Postero-lateral sulci teething troubles are experienced because of the dense connective present there.

At birth, the mandibular gum pads are posterior, and progressively move forward until the Ds erupt, at which time the relative antero-posterior relationship of the dental arches is established.

Friel[34] considers the development of the occlusion from birth to adulthood. At birth the gum pads are divided into sections corresponding to the underlying deciduous teeth, and only the 1st deciduous molar areas occlude. The teeth are tightly packed in the smaller arches, and incisors are rotated.

In the deciduous dentition, Baume [36] and Miss Clinch[37] have both reported an "anthropoid" space mesial to the maxillary canines, and distal to the mandibular canines.

In 1908 Chapman pointed out that the distal surfaces of the upper and lower second deciduous molars end flush. Also, there is a greater difference in size between the maxillary deciduous and permanent incisors than in the mandibular. Seipel found that the maxillary permanent incisors averaged 7.2 mms more than their deciduous predecessory, and the mandibular permanent incisors averaged 5.1 mms more than the deciduous.

Friel states that these two factors are allowed for by a greater forward movement of the mandibular arch. Friel's illustrations show attrition of the incisors and canines, and buccal cusps of lower deciduous molars, lingual cusps of upper deciduous molars, at the age of six years. This attrition permits the mandible to move forward two mms.

Up to this stage, it has been necessary to obtain increased space for the permanent teeth, but with the shedding of the deciduous canines and molars, too much space is provided for the permanent canines, and bicuspids. This applies particularly in the mandibular arch. According to Friel, this space does not completely close, in the maxillary arch, a small space remaining between the laterals and canines (a persistence of the "anthropoid" space). However I have not seen this space very frequently in my experience. The remaining space is closed by the larger permanent canine, and by a mesial drift of the first permanent molar.

In the mandible, the space is completely closed. The lower first permanent molar moves farther forward than the upper. Thus the molar relationship changes, the 6⌉ being farther forward in the permanent dentition than at 8 years of age. The last major change that occurs in the occlusion of the permanent teeth is due to <u>wear</u>

(a) Interproximal

(b) Occlusal.

The Interproximal wear reduces the lengths of the arches. The occlusal wear shortens the height of the teeth, so that in occlusion the mandible swings upwards and forwards, resulting in an edge to edge incisor relation.

Dr Begg[38] describes the interproximal and occlusal wear of the Australian aboriginal dentition. He says that this "Stone-Age" dentition is anatomically correct occlusion, and for it to develop, it is necessary that the inherited sizes of the teeth, before wear, should be greater than the available base bone. In the deciduous dentition, occlusal and interproximal wear result in an edge to edge bite, and the $\left.\frac{6}{6}\right|$ erupt farther mesially than in civilised man. In the permanent dentition, by the time the third molars erupt, there has been about 14 mms of inter-proximal wear in the arches, resulting in adequate space at the distal ends for unimpeded eruption of the 3rd molars.

Belger[39] studied cephalometrically 47 subjects wearing bite plates. He recorded the physiologic vertical growth obtained in the premolar, molar, and lower incisor areas.

He first measured eruption and elevation increments for one year in patients who were under observation, preparatory to treatment. He found

(1) Height increase due to normal growth was more in lower bicuspid and molar regions than in uppers.

(2) With biteplate, increment in upper bicuspid and molars exceeded lowers.

(3) With biteplate in conjunction with fixed appliances, lower eruption exceeded uppers. Belger feels that this is due to unlocking the crowding of the lower arch.

(4) In all cases, the lower incisors either showed no change,

or a slight increase in height.

Brodie[40] published in 1953 results of studies of growth of 19 individuals from the 8th to 17th years. He concluded that the head is a complex of different parts, each having a high degree of independence, only limited by the joining of the parts by sutures and joints.

Brodie found

(1) Nasal Floor : fairly stable, if any change occurs, anterior end drops.

(2) P.T.M. (Junction between the pterygoid process, and Maxillary Tuberosity) the most stable point in an A/P direction in the facial area, Drops straight downward from its position at 8 years (also applies to PNS)

(3) Occlusal Plane Stable in 50%. In others drops slightly at posterior

(4) Mandibular Border Stable in over 50% of cases. In others drops at posterior

(5) Angle NSGN (which relates the Y axis of growth, and the anterior cranial base). Stable in 11 of 19 cases, 1 case decreased, 7 cases increased (maximum 4° usually about 2°).

(6) Angle SNGN In no case a backward movement. Four cases stable, remaining 15 cases showed forward movement of GN point ranging from 3° to 6°.

(7) Anterior Nasal Spine and Pogonion continue downward and forward. Dental arch and alveolus move more slowly, and thus drop behind. This decreases the prominence of the denture.

However inclination of incisors may become less procumbent, or remain unaltered.

(8) Angle B.S.N. varies; may decrease, remain constant,

or increase. Brodie feels that there does not appear to be a correlation between this angle and the behaviour of the "facial mask " as indicated by movements of the chin point.

(9) Porion. Large range of variation. Varies from straight backward to straight downward. Brodie feels that there does not appear to be a correlation with

(a) Opening or closing of angle BSN.

(b) Behaviour of the chin point.

Brodie concludes that, although these growth patterns show variations, each individual's growth pattern is markedly stable. A similar conclusion was drawn by Lande[41], who studied the behaviour of the male bony profile during growth. Lande studied 34 males cephalometrically, and found that the convexity of the face nearly always decreased. He also found that the maxilla showed very little change in relation to the brain case, but that the mandible tended to become more prognathous, particularly after 7 years of age.

Lande found that alveolar bone growth does not keep pace with the growth of its skeletal base in a horizontal direction, and that the majority of cases studied showed the same general tendency of growth behaviour, regardless of their facial type.

A review of Dimensional changes in the human head and face in the 3rd decade of life was made by Baer[42] (1956). Material was collected by the U.S.Army Anthropometric Survey of 5688 males and 7420 females, aged 19 - 33.

Dimensions selected for Study

(1) Head Length

(2) Head Breadth

(3) Head Circumference

(4) Total face height

(5) Bizygomatic Diameter

(6) Nose Height.

In the female series, only total face height was recorded.

The nature of dimensional change in these six anthrometric measurements were assessed by fitting curves mathematically to the data obtained.

Indications : During the 3rd decade

(a) the three head dimensions do not change significantly in proportion.

(b) the three facial dimensions increase in size. Face and Nose height exhibit a curvilinear pattern of slow deceleration. Bizygomatic width is characterised by a slow linear uncrease, with no indication of an approaching plateau.

For females the face height does not appear to increase appreciably during the third decade.

The study supported the general conclusions of Hellman (1927), Hrdlicka (1936) and Lasker (1953) that the human male face continues to increase in size in adulthood.

However the study showed particular correspondence to the findings of Buchi (1950 on Swiss males, and Hooton and Dupertuis (1951) on Irish males.

Hooton and Dupertuis found that total face height reached a maximum at 30 - 34 years, but that face breadth reached a maximum at 60 - 64 years.

Buchi's findings were of similar degree.

Salzmann [45] summarises that these studies reveal that the human cranium undergoes an early rapid expansion in conjunction with the growth of the brain, while the face shows sustained growth of longer duration, related to the development of occlusion. They show, further, that females achieve their greatest gain in facial growth earlier than males and tend to be about one dental stage in advance of males during the period of the mixed dentition.

The continued growth of the male face into young adulthood then represents the terminal phase of the childhood pattern.

A cephalometric study of the growth of the cranial base and its components was reported by A.G.Brodie[44] Jnr. in 1955.

Brodie used Basion (a midline point) as the posterior terminal landmark. He considered the cranial base in the midsagittal plane to be made up of

(1) The Basilar part of the occipital bone (beginning of Basion)

(2) The Body of the Sphenoid

(3) The Cribriform plate of the Ethmoid.

Serial data for each individual was studied from 3-18 years. In general, the findings revealed that the incremental growth curve of the whole cranial base resembled the neural type of Scammon (1936), and that the relative contribution of any one part, once established, did not change significantly during the period.

The cranial base length was approximately doubled over the post-natal growth period. At approximately 3 years of age, more than 50% of the complete growth was attained, and almost 90% of growth was completed by the thirteenth year.

Influence of Vitamins (Weinmann and Sicher, Salzmann (45))

These food elements are ingested in small quantities and are distributed by the blood stream. They act in specific ways on the different tissues, and are essential for normal growth and development

Vitamin A.

Fat soluble, contained in eggs, milk and liver, yellow and green vegetables, contain carotene (provitamin A) which is transformed to Vitamin A in the body.

Stored in great quantities in the liver.

Deficiency

(A) General Atrophy of epithelial tissues and keratinisation, xerophthalmia, respiratory infections, poor appetite and indigestion.

(B) Dental Disturbances in differentiative and appositional growth of the developing teeth. Tooth calcification is disturbed, eruption and general growth and development retarded. Periodontal tissues are disturbed.

Vitamin B Complex

Most important are

B1 or Thiamin

B2 or RIBOFLAVIN

B12 - important for erythropoiesis.

Filtrate Factor - mainly Pantothenic Acid

Contained in lean meat, especially pork and liver, and in certain vegetables e.g. potatoes, carrots, and rice polishings.

Deficiency

Riboflavin (B2) can result in skeletal malformations e.g. shortening of mandible, underdevelopment of maxilla.

Deficiency of nicotinic acid produces gingival inflammation.

Deficiency of the filtrate factor leads to osteoporosis of alveolar bone particularly the maxilla.

Vitamin C

Citrus fruit, green peppers, leafy vegetables.

Deficiency

Scurvy, Oral symptoms are swelling and bleeding gums, loosening and loss of teeth. Severe pain in joints.

Dentine formation decreased and finally ceases. Osteoporosis evident. The periodontium shows a typical change - the well organised principal fibres which act as suspensory ligaments lose their functional arrangement and are replaced by loose connective tissue.

Vitamin D.

Sources Egg yolk and dairy products, Halibut and codliver oils. The ordinary mixed diet is poor in vitamin D, but contains ergosterol (Provitamin D), which is stored in the skin, and is changed to vitamin D by irradiation with ultra-violet rays (sunlight).

Action of vitamin D

Vitamin D regulates the calcium-phosphorus metabolism.

Deficiency

Leads to rickets, a disease of early childhood, with an onset mainly between the third and eighteenth months of life. It is also met between the 6th and 15th years.

Bone.

The first phase of the development of bone tissue (formation of the organic matrix by osteoblasts) is undisturbed. However the second phase - calcification - does not take place. The uncalcified osteoid tissue is highly resistant to osteoclastic resorption, and therefore persists in excessive amount. If vitamin D is added to the diet, calcification rapidly occurs.

Bones

Changes in the skull are especially marked, and are often the first clinical manifestations of rickets, because the brain and skull show a greater rate of growth during the first year of life than any other part of the body. In rickets, the greater the rate of growth, the greater the alterations in the bone.

Excessive growth of the cranial bones, lack of modeling resorption, and excessive sutural growth, result in the head appearing too large, and this is accentuated by the underdevelopment of the body.

The forehead bulges, and the growth of the mandible is more affected than that of the facial skeleton, making Rickets one of the actiological factors in facial disharmony.

Tooth Eruption :

Impairment of cartilaginous growth at the mandibular condyle results in underdevelopment of the ramus and retards tooth eruption because of lack of vertical space between the jaws. Since tooth eruption, and the shedding of deciduous teeth are also accompanied by resorption of bone and tooth substance, the inhibition of resorption in Rickets will result in a second retarding factor in the tooth eruption. Tooth positioning is also affected, since tooth movements during eruption depend upon bone resorption at the right time and place.

Nutrition

Salzmann (Book "Principles and Prevention" 1957) states that nutrition in relation to orthodontics is most important during the prenatal period when the toothbuds are forming, and during the active growth period of childhood. Malnutrition or dietary deficiencies can result in distorted growth.

Prenatal Nutrition.

Adequate vitamis D and calcium are essential for normal development of bones and teeth. Iron is necessary to prevent anaemia. Vitamin A prevents certain congenital malformations. In experiments, lack of riboflavin resulted in shortening of the mandible, cleft palate and other skeletal malformations in rats. Lack of iodine can produce cretinism.

Acute folic acid deficiency has been shown to produce palatal clefts, general growth retardation and abnormalities in rats.

In rats again, lack of vitamin A produced structural abnormalities in the offspring. However excessive vitamin A also produced cranial abnormalities.

In post-natal growth, there are variations in the ability of different children to assimilate the nutritive values of food. There have been cases of twins, eating similar diets, where one has developed rickets and the other remained healthy.

Salzmann states that growth failure is usually associated with feeding problems, circulatory, gastro-intestinal diseases, and allergies.

Calcium, phosphorus, and vitamins C and D are especially necessary for dentofacial growth and development.

During adolescence, growth is accelerated, reaching a peak in girls at 13, boys at 16. The B.M.R. of adolescent boys is 11-25% higher than in male adults.

If growth is depressed, vitamins B1 and B12 stimulate the appetite. They also assist in maintaining a normal carbohydrate metabolism, a properly functioning gastro-intestinal tract, and the regulation of protein and lipid synthesis.

To maintain sound healthy teeth it is necessary to

(1) Restrict the intake of sweet foods

(2) Ensure that the diet is balanced and contains the necessary vitamins and minerals

(3) Foods requiring vigorous chewing have a beneficial physical effect.

<u>Calcium</u> is normally present in the bloodstream in concentrations of 10-11 mgms per 100 ccs. of serum. In small children, illnesses affect the deposition of calcium in bone.

Calcium intake exceeds that excreted during growth, pregnancy, pituitarism and after a period of deficient calcium intake.

Calcium excretion exceeds intake in childhood rickets, osteomalacia, and hyperparathyroidism.

<u>Foods of high calcium content</u>

Milk, cheese, cauliflower, celery, beet greens.

<u>Fluorides</u>. The presence of one part per million in the drinking water reduces dental caries by approximately 50% .

<u>Effect of pressure on bone</u>

Weinmann and Sicher describe the influence of increased pressure or tension on bone and bones

(1) Increase of pressure or tension beyond the limits of tolerance leads to the destruction of bone by resorption

(2) Within the limits of tolerance, an increase of the normal forces of pressure or tension leads to formation of new bone, if the forces act upon surfaces adapted to resist tension or pressure.

(3) If pressure, whether continuous or intermittent, interferes with the blood supply or blood drainage of bone tissue, osteoclastic resorption of bone results. (4) If the vascularized connective tissue is destroyed, bone resorption is delayed and the necrotic bone is finally removed by retrograde or undermining resorption.

These principles are important, as the fact that teeth can be moved orthodontically depends upon them.

ENDOCRINES.

The influence of the endocrine glands on growth and development has been covered by Schour and Massler, Salzmann, Weinmann and Sicher, Shelton, Cross, Downs and others.

Functions of the Endocrine

Schour and Massler summarise the functions. The secretions enter the blood-stream, and influence the activity of distant cells, where they act as catalysers which accelerate or decelerate basic cellular processes such as growth, differentiation, and metabolism.

These hormones do not initiate new cellular or metabolic activities, but regulate their rate of development.

The endocrine effects will differ in growing and non-growing tissues or sites, and thus the result will vary with the age of the patient.

Weinmann and Sicher[13] lists the glands which are known to influence bone and bones as

(1) Pituitary

(2) Thyroid

(3) Sex glands, or gonads

(4) Parathyroid glands

(1) Pituitary of ectodermal origin, housed in Sella Turcica.

Function The master endocrine gland of the body, it regulates

(1) Growth

(2) The metabolism of nitrogen and water. It secretes many hormones,

which act upon other hormones.

(1) Growth Hormone

Secreted by the acidophilic cells, controls the rate of growth of all organs and tissues,(except uterine). Has no influence once growth is complete.

(2) Gonadotrophic Hormone

Secreted by basophilic cells. At puberty, cause growth to be inhibited and slowed down. Active growth ceases, and the epiphyses close. Lack of the gonado-trophichormone results in eunuchoid gigantism due to failure of epiphyseal closure.

Hypopituarism

child small, well formed, intelligent.

Craniofacial resembles child of a much earlier chronological age.

Jaws underdeveloped, but teeth are of normal size and become crowded and/or submerged. Mandible may be distally placed due to slowing down of condylar growth.

Eruption of teeth is in keeping with developmental age. Therefore patient may have a chronological age of 18, skeletal age of 8, denture of a child of 8-10.

HYPERPITUITARISM

The effect depends upon the age at which the onset of the disease occurs.

(a) Gigantism occurs when the onset is before the age of six years, when all structures are increasing rapidly in size. We see uniform overgrowth of all parts of the body - unusual height, but with the proportions of a child.

(b) Juvenile Acromegaly Hyperpituitarism between 6 years of age and puberty. Growth is gradually becoming localised, and the overgrowth is evident only in those structures which are still growing. We see abnormal height with fair proportions, but huge hands and feet and a very long face and prognathic jaw.

(c) Adult Acromegaly results in overgrowth of the face, hands and feet, spine and clavicle (where adult growth persists). The joints become knobby and the fingers and toes are very wide, and appear short and blunt.

Jaws in Acromegaly

Supra-eruption of teeth, overgrowth of alveolar process, spacing of teeth. In the Mandible we see increased height of the ramus and Class III relation (growth is accelerated even beyond the general overgrowth of the face).

In Maxilla, sutural growth is increased to some extent.

Teeth.

Eruption accelerated. Supra-eruption evident, with abnormally great distance between root apices and jaw base, and wide spacing of the teeth. The enamel and dentine of the teeth are unaffected, but hypercementosis is apparent.

(2) THYROID GLAND Produces a specific hormone THYROXIN which regulates the Basal Metabolic Rate. Its effects on growth and development are secondary to those upon the rate of cellular metabolism and cellular differentiation.

Hypothyroidism Depression of B.M.R. (rate of cellular metabolism) growth virtually stops in all tissues. Salzmann (Book) lists 4 types, depending on time onset.

(1) Hereditary Hypothyroidism : Of genetic origin. Believed to be the cause of infantile Hypothyroidism.

(2) Cretinism. Hypothyroidism occurring at birth. Results in under-stature and disproportion. Bone growth almost completely arrested, soft tissue less so, so dwarf is generally obese and mentally deficient.

Characteristic facies, denture prominent and crowded as teeth and alveolar bone are less affected than base bone.

Cretin aged 20 may have bone age 3 years, dental age 8 years.

The teeth are normal in structure, according to Weinmann and Sicher. However Salzmann states that they show structural defects. They are retarded in development, eruption is markedly retarded, and deciduous tooth shedding is delayed.

Naso-orbital configuration, and upper and lower body segment ratio, remain infantile.

(3) Juvenile Myxedema : Hypothyroidism occurring after age of six years, but before puberty. Characterised by a decrease in the rate of maturation. Calcification of teeth and bones is delayed; deciduous teeth shedding and permanent teeth eruption are delayed. Deciduous teeth may be found coexistent with permanent teeth up to the 3rd decade of life. Tooth crowding is evident.

(4) Adult Myxedema

Hyperthyroidism rare, as the condition is readily diagnosed and treated surgically.

Symptoms Increase in BMR.

Increase in temperature

Perspiration

Nervous irritability

Exophthalmus

If not treated, increase in growth and development is seen - e.g. child of 5, bone age 10-12, dental age 9.

(3) GONADS. hace exocrine and endocrine function. The hormones initiate puberty, when maturation processes begin.

HYPOGONADISM

(a) If before puberty, we see typical eunuchoid gigantism. Closure of epiphyseal growth sites may not occur till 40 years of age.

Muscylature is underdeveloped but limbs, fingers and toes grow very long.

(b) If in adult, result is obesity.

Jaws Increased bone formation. Jaws massive and ramus appears short. However, the dysplastic effects of acromegaly are not evident. Teeth are normal.

Hyperparathyroidism

Osteoporosis, or Osteitis Fibrosa Cystica (Non Recklinghausen's Disease)

Bones are demineralised and become soft, leading to skeletal deformities. Cross points out that dental X-rays may offer the first evidence of the onset of the disease. As a result of the bone changes, drifting of teeth occurs producing malocclusions.

However it is important to note that the teeth (when completely calcified) are never decalcified, even when the bones are being decalcified (e.g. in pregnancy, lactation, parathyroid tumors).

However, in young patients where calcification of teeth is incomplete, demineralisation of the skeleton prevents normal tooth calcification.

Cross[47] has written an article demonstrating the relation of the endocrines to orthodontic diagnosis and treatment planning. He points out that hypothyroidism is probably the most responsive to medication of endocrine dysfunctions. However he records that if a child has reached the age of 10 years without receiving thyroid therapy, permanent damage to the central nervous system will have occurred.

Cross points out that only a small proportion of orthodontic patients have an existent endocrine dysfunction, but it is important to recognise them when they present.

Shelton[48] has listed physical signs, as seen in the dental chair that would point to Endocrine or Metabolic disturbance. He notes personality, weight, height, configuration, skin, hair, eyes, nose, extremities, mouth and neck.

Schour[46] notes that because endocrine disturbances are of systematic and not local origin, they either retard or accelerate the downward and forward growth of the face, but <u>do not distort</u> the growth. Changes in craniofacial proportions are not usually noticeable before 6 years of age.

Salzmann [1] summarises the effect of endocrine disturbances.

(1) <u>Teeth</u> Disturbances during pre-eruptive period can affect the histologic structure and physical appearance of the teeth. After the hard tissues are formed, they are unaffected by endocrine disturbances.

(2) Periodontal changes

(3) Retardation or acceleration of the downward and forward growth of the face result in <u>characteristic</u> facial appearances

(4) Changes in eruption and alignment of teeth

(5) Abnormalities in the relationship of the teeth and jaws to each other, and of the jaws to the face and cranium, depending upon the age of onset of endocrine dysfunction. Disturbances of craniofacial proportions occur during the localised dentofacial differentiative growth period (after age 6 years).

Seipel, van Wagenen and Anderson[49] investigated the effects of sex hormones on Macara Mulatta monkeys. They found that both estrogens and androgens produced precocious skeletal development, but accelerated the osseous unions, thus resulting in smaller than normal skeletal dimensions (as opposed to castrates where growth is slower than normal, but due to late closure of epiphyses, ultimate height is larger than normal). It was necessary to administer hormone treatment for a prolonged period during early age and in large doses to produce any remarkable changes. Only the monkeys that received hormone treatment for a prolonged period during early age, and in large doses, showed any remarkable changes.

Effect on Skull and Jaws

General reductions in size of the testosterone -treated animal, except for transverse skull size.(Castrate's head is also somewhat smaller than normal).

The dentition seems to be subjected to the same changes as the skeleton - namely, following an initial acceleration of tooth eruption there is a marked retardation and cessation of development - we see

(1) Lack of alveolar growth, with open bite tendency

(2) Lack of mesial migration of teeth in relation to alveolarzygomatic crest

(3) Delayed eruption and impaction of molar teeth

(4) Disturbed root development - shortened and crooked roots of the teeth.

Conclusions

A Class III malocclusion with mandible in a protrusive,open-bite position, has been observed in testosterone-treated monkeys.,

Causes (1) Mandibular body less reduced in size than upper jaw

(2) Arrest of growth in a dorso-lateral direction of porion and articular area of skull -, mandibles thus in a more ventral position

(3)Decreased oral space + concomitant muscular hypertrophy and tongue pressure also advances the mandible ventrally. This tongue pressure + mandibular malformation and arrest of condylar growth explains the open bite.

Salzmann[2] has written a very comprehensive article on general growth acceleration and retardation in relation to dentofacial development. He makes the point that the Orthodontist must study the child as a whole, and not merely the oral malformation. There are aberrations of physical growth and development of

(Genetic
(
(Prenatal
(
(Postnatal
(
(Local
(
(Systemic origin which must be taken into account, if successful terminal results of treatment are to be obtained.

Salzmann presents information which he has obtained on the influence of systemic disturbances on dentofacial growth and development.

Ontogenetic growth and development follow a phylogenetic pattern and are influenced by genetic endowment

Postnatal and terminal growth are influenced by environment.

An adequate supply of

(Amino acids
(
(Vitamins
(
(Minerals
(
(Oxygen is necessary for normal growth. Lack of these, presence of disease, or Hormonal imbalance, especially pituitary, thyroid, adrenals, or gonads, can interfere with general (including dentofacial) growth and development.

Criteria for assessing Status and Progress of Growth and Development

(1) Height and weight

(2) Bone Age

(3) Dental, Age

(4) Skeletal Proportions

(5) Craniofacial contours

(6) Facial features

(7) Endocrine balance.

Salzmann lists the various types of dwarfism.

(1) <u>Primordial Dwarfism</u> :-

Present at birth. Normal

osseous)
dental) development
sexual)
mental)

but extreme retardation in physical growth.

(2) <u>Ateliotic Dwarfism</u>

Generalised under-development. Normal proportions intelligence -, patient appears to be a miniature adult.

(3) <u>Achondroplastic Dwarfism</u> :-

due to abnormal osteogenesis. There is premature closing of epiphesis.

Chondrification is disturbed, but membrane bones develop normally -, characteristic physical proportions.

Dental development is unaffected.

(4) <u>Hypothyroid dwarfism.</u>

(5) <u>Hypopituitary Dwarfism.</u>

(6) <u>Delayed Adolescence,</u>

Some dwarfing and delay in epiphyseal closure. No endocrine or metabolic disturbances. Skeletal proportions normal. Slow starters and finish late.

May be (a) genetic origin, or

(b) associated with nutritional disorders or disease.

Sexual development normally begins when bone age reaches 12 years and may be accompanied by growth acceleration. In delayed adolescence sexual development occurs much later. Epiphyseal closure and growth cessation also occur later than usual, and the patient may reach normal height, but at a later age.

(7) Brain Defects

Hypothalmic disturbances.

(8) Progeria.

Premature aging and dwarfism with micrognathia and crowding of teeth.

(9) Endocrine Disturbances

Singly or in combination cause disturbances of growth and development

(a) Hypo or Hyper pituitarism

(b) Hypo or Hyper thyroidism

(c) Adrenocortical insufficiency or overfunction

(d) Gonadal disturbances

(e) Sexual precocity with early closure of epiphyses.

Factors Responsible for Growth Disturbance

(1) Genetic or Constitutional Factors :

May by Familial or Sporadic

e.g. (a) Ovarian agenesis

(b) Organiser hormone deficiency which interferes with tissue differentiation during the embryonic stage.

Examples of genetic factors acting directly on the end organs,

Achondroplasia

Mongolism

Brimordial dwarfism

Heriditary craniofacial dysostosis

Disturbances in body build and size,

Sensitivity of the sex organs.

Hypothalmic centre disturbances of genetic origin can alter the pituitary or other endocrine gland or may act directly on various body organs through the sympathetic nervous system.

(2) Nutritional Deficiency. ~~e.g. Disturbed CAP~~.

(3) Metabolic Disturbances (1)

(1) eg disturbed CaP Metabolism

(2) Childhood diabetes

(3) Hypocaliaemia.

(4) Chronic Disease

e.g. Celiac Disease

Hepatic Deficiency

Allergy

Rickets

Chronic Renal Disease

Cystic Fibrosis of the Pancreas

Childhood Tuberculosis etc,.

(5) Bone Dyscrasias

Bone is formed when Phosphatase converts organic phosphorus into inorganic PO4. The solubility product of Ca and PO4 is thus exceeded and $Ca_3(PO_4)_2$ is deposited in the organic matrix of bone and in the teeth. Examples of bone dyscrasias are (Chondrodystrophy,

(Dysostosis

(Osteogenesis imperfecta

(6) Circulatory Diseases

e.g. Cardiac Malformations,

Pulmonary Deficiencies

Other conditions in which oxygen intake is interfered with.

(7) Endocrine Balance :-

Due consideration of endocrine correlation is indispensible in the diagnosis, prevention, interception, and treatment of dentofacial abnormalities.

Hormones can influence

(a) Growth

(b) Maturation of skeleton.

Effects of endocrine dysfunction may show up

(a) Directly as Disturbed tooth formation and eruption

(b) Indirectly by interfering with the normal rate and direction of growth, and the physical characteristics of the bones.

The soft tissues of the mouth are also affected by endocrine disbalance.

Gigantism

may be (Normal, Normal proportions
(
(Eunuchoid. Disproportion, long arms and legs, infantile facial features,
(
(Acromegalic.

Gigantism with Adrenogenital Syndrome

Excessive masculinization in females and rapid growth in height, Dental development practically unaffected.

(1) Pituitary Gigantism

(adenoma of pituitary)

in child	gigantism
in adult	acromegaly

(2) Hyperpituitarism

In early life (1) Early eruption of deciduous teeth

(2) Overgrowth of jaws

(3) Increased density of jawbones

(4) Prognathism

(5) Irregular spacing of teeth.

(3) Hyperthyroidism

May be increase in height

Rate of growth and osseous development accelerated

Dental development may be accelerated.

Engel[50,51] and Brodie[51] studied 19 cases of arrested growth of the condyles. Normal growth of the mandible depends upon synchronous co-ordination of the growth activities of the various mandibular growth centres.

Growth disturbances of condyles may be unilateral or bilateral.

Unilateral growth arrests are most frequently associated with

(1) Trauma (local) resulting in fractures, or disturbances of bone-forming cartilage,

(2) Sequel of mastoiditis or middle ear infections,

(3) Haematogenous infections, or infections which spread from dental area and become localised in the joint and lead to interference with chondral activity or to ankylosis and/or functional limitations.

Bilateral Arrests, According to Engel, are almost always due to (4) juvenile rheumatoid arthritis.

More rarely, neoplasms. congenital absence of structure, or endocrine disturbances may be responsible for condylar growth arrests.

(1) to (4) result in scarring, and early ossification of the condyle head.

The severity of the deformity is related to the time and duration of the arrest. The severity of the dysplasia is more pronounced when onset is at an early age, during period of rapid growth. Sometimes the arrest is succeeded by a period of growth at a decelerated rate. As surgical intervention imposes another severe growth arrest, it is essential to make serial records, over a period of 2-3 years, before surgery (in case of ankylosis) to determine whether any growth activity is continuing.

SYMPTOMS

Unilateral Class II relation on the affected side, and a pronounced mandibular mid-line shift to this side. A pronounced notch can be palpated at the Ramus - Body junction on the side of the arrest. The external pterygoid muscle is inactivated, and mandibular movements, particularly lateral excursions, are affected.

Bilateral symmetrical deformity (Vogelgesicht), with severe Class II malocclusion, and tendency to open bite. Notching noticeable on both sides, and jaw movements are usually limited.

Facial Patterns

(1) Failure of forward development results in an acute S.N. Gn angle

(2) Failure of ramus height growth results in a larger than normal S.N. - Mandibular Plane Angle.

This type of facial pattern is seen in some extreme Class II Div.I (Angle) malocclusions a nd Engel and Brodie feel that growth disturbances of the condyle may be an aetrological factor.

Korkhaus[52] points out that disturbances of growth of the mandible can be fairly easily traced. However disturbances in the development of the maxilla present a more complicated problem. The growth of the upper jaw and middle face is dependent upon the synchondroses of the base of the skull, and the facial sutures.

Synchondroses of base of skull

(1) Sphenoethmoidal - disappear at age 7 years

(2) Intersphenoid - normally ossifies at birth

(3) Spheno-occipital - continues until 18 - 20 years

(4) Intraoccipital - disappears at age 4 - 5.

Growth in these synchondroses according to Weinmann and Sicher is similar to epiphyseal growth in long bones. If growth of the cartilage is inhibited, the result is shortening of the skull base in a sagittal direction, coupled with an underdevelopment of the upper and middle face and retrusion of the upper jaw.

Korkhaus points out that the growth of the cerebral skull is dependent upon the growth and size of the brain. Consequently as a result of retardation in the development of the base of the skull the brain must extend itself excessively in another direction. Korhaus presents a case of turrecephaly (tower skull) in a man of 24½ years. The base of the skull is retarded in Antero-posterior growth, and this underdevelopment of the middle face and upper jaw, associated with a normal mandible, results in a Class III relation of the jaws (Korkhaus terms this a "false progenia").

Korkhaus also presents photographs and cephalometric radiograms of a pair of 50 years old male mono - ovular twins. In one of the twins there is under-development of the skull base and tower skull and it is interesting to see the comparison with the normal twin. The vertical development of the face, the rami of palate are almost identical. However in the affected twin the maxillary sinus the floor of the nose and the orbits are smaller antero-posteriorly. The protruded upper incisors just meet the mandibular incisors edge-to-edge. Korkhaus feels that endocrine disturbances, particularly the hypophysis, may be partly responsible for tower skull.

A shortening of the skull base (and also of the length of the extremities) is also seen in achondroplastic dwarfs. The upper jaw is characteristically underdeveloped and retruded, and the normal development of the mandible results in a "false progenia". Weinmann and Sicher [13] explain that the cartilage on the mandibular condyle causes growth by surface apposition and is unaffected in chondrystrophy, as opposed to the interstitial growth of the epiphyseal cartilage and the synchondroses at the base of the skull where growth is inhibited.

R E F E R E N C E S.

1. Salzmann, J.A. : Principles of Orthodontics. Lippincott 1950.

2. Salzmann, J.A. : General Growth Acceleration and Retardation in Relation to Dentofacial Development. A.J.O. 40: April 1954.

3. Wetzel, Norman C. : Physical fitness in terms of physique, development and basal metabolism, with a guide to individual progress from infancy to maturity. A new method for evaluation. Jour. Amer. Med. Asso. 116 : 1187-1195, 1941.

4. Krogman, W.H. : Growth Theory and Orthodontic Practice , Angle Orthodontist 10 : 179, 1940.

5. Scammon, R. : Measurement of Man. Rochester Uni. of Minnesota Press, 1930 p.p. 173-215, Reported by Krogman.

6. Schulz, A.H. : Studies on the Evolution of Human Teeth, Dental Cosmos 67 : 935 - 947 1925 (reported by Krogman)

7. Ruprecht, O. : A Study of the Heredity of the Anomalies of the Jaws, A.J.O. & OS. Aug. 1939.

8. Johnson, A.Leroy. : The Constitutional Factor in Skull Form and Dental Occlusion, A.J.O. & OS 26 : 627 - 63, 1927. (reported by Krogman)

9. Brader, Allen C. : "Historical review of Research Findings of Growth and Development Prior to the Introduction of Roentgenographic Cephalometry". Angle Orthodontist, Vol. 26 : 1 -9, Jan.1956.

10. Brodie, A.G. : Appraisal of Present Concepts in Orthodontia. Angle Orthodontist Vol. XX : 24 - 37 1950.

11. Hellman, M. : Some Morphological changes in the Jaws Produced by Orthodontic Treatment. Dental Items of Interest, 37 : 161 - 185 (reported by Brader). 1915

12. Hellman, M. : "Dimensions versus Form in Teeth and their Bearings on Morphology of the Dental Arch. Int. J. of Ortho. 5 : 615-651. 1919

13. Weinmann & Sicher : Bone & Bones, 1955.

14. Broadbent, B.Holly : The Face of the Normal Child. Angle Orthodontist October 1937.

15. Todd, T.Wingate : The Orthodontic value of Research and Observation in Developmental Growth of the Face. Angle Orthodontist 1 : 67, 1931.

16. Broadbent, B.Holly : A new X-ray Technique and its application to Orthodontics, Angle Ortho. 1 : 45, 1931.

17. Lewis, S.J. : Some aspects of Dental Arch Growth, J.A.D.A. 23 : 277-294,1936.

18. Brodie,Alan G. : On the Growth Pattern of the Human Head from the 3rd month to the eighth year of life. American Journal of Anatomy, March 1941.

19. Ortiz, M.H : On the Growth of the Human Head from Birth to the 3rd Month of Life, Masters Thesis, Univ. of Illinois, 1945.

20. Brodie, Alan G : On the Growth of the Jaws, and Eruption of the Teeth. Angle Ortho. XII July 1942.

21. Applebaum, Edmund : Integration of Anatomic and Cephalometric Studies of Growth of the Head, A.J.O. 39 : 612, 1953.

22. Tirk, Theodore M : A study of the growth of the head by the Planimetric method. Angle Ortho. XVIII, P.76-93 1948.

23. Orban, Balint : Oral Histology & Embryology, C.V.Mesby 1944.

24. Strang, R.H.W : A Text Book of Orthodontia. Lea & Febiger 1950.

25. Lewis, S.J. : Some aspects of Dental Arch Growth, J.A.D.A. 23: 277 1936.

26. Moore,A.W. : Head Growth of the Macaque Monkey as revealed by vital staining embedding and undecalcified sectioning, A.J.O. 35: 655, 1949.

27. Gans, B.J, and Sarnat,B.G,: Sutural Growth of the Macaca Rhesus Monkey : A Gross and Serial Roentgenographic Study by Means of Metallic Implants, A.J.O. 37 : 827, 1951.

28. Scott, J.H : Growth at Facial Sutures, A.J.O. 42 : 381 1956.

29. Rogers, Alfred P ; Evolution, Development, and application of Myofunctional Therapy in Orthodontics, A.J.O. & O.S., 25 : 1-19 1939.

30. Scott, J.H.: The Growth and function of the muscles of Mastication in Relation to the Development of the Facial Skeleton & of the Dentition. A.J.O. 40: 429, 1954.

31. Cohen, Michael M, and Garn, Stanley Marion : Factors in Occlusion. A.J.O. 40 : 671, 1954.

32. Broadbent, B.Holly : Ontogenetic Development of the Occlusion. University of Penn Press, 1941.

33. Sillman, J.H : Serial Study of occlusion, A.J.O. 34 : 969 Dec. 1948.

34. Friel, Sheldon : The Development of the Ideal occlusion of gum pads and teeth. A.J.O. 40 : 3 1954.

35. Dewel, B.F. The Upper Cuspid. Its Development and Impaction. Angle Ortho. XIX No.2 P.79-90 April 1949.

36. Baume, L.J : Physiological tooth migration and its significance for development of occlusion. J.Dental Research 29: 1950. (reported by Friel)

37. Clinch, Lila M : The British Society for the Study of Orthodontics, 1951 (reported by Friel)

38. Begg, P.R. : Stone Age Man's Dentition, A.J.O. 40 :298, 1954.

39. Belger, Ilhan : Cephalometric Analysis of growth in subjects using Biteplate, Angle Orthodontist 26 : 1 Jan. 1956.

40. Brodie, A.G : Late Growth Changes in the Human Face, Angle Ortho. Vol.23 No.3, July 1953, pp. 146-157.

41. Lande, Milton Jay : Growth Behavior of the Human Bony Profile as revealed by serial cephalometric roentgenology, Angle Ortho. 22: 2 April 1952.

42. Baer, M.J. : Dimensional Changes in the Human head and face in the 3rd decade of life. Am. J. Phys. Anthropology, 14 : 555-575, Dec. 1956. (Reported by Salzmann, A.J.O. July 1957)

43. Schaeffer, A : Behaviour of the Axis of Human Incisor teeth during growth . Angle Orthodontist XIX, 4 Oct. 1949.

44. Brodie, Alan G. Jnr.: Behaviour of the Cranial Base and its components, as revealed by serial Cephalometric Radiograms. Angle Orthodontist 25 : 3, July 1955. pp. 148-160.

45. Salzmann, J.A. : Orthodontics, Principles and Prevention. Lippincott 1957.

46. Schour and Massler : Endocrines and Dentistry. J.A.D.A. Vol.30.Nos.7,9,11,1943.

47. Cross, Sydney : Endocrines - their relation to orthodontic diagnosis and treatment planning. A.J.O. 34 : 418 May 1948.

48. Shelton, E.K. : Osseous Development as an Index of Metabolic Speed, Endocrinology 17 : 667 - 676, 1933 (reported by Sydney Cross)

49. Seipel, C.M, van Wagenen, G, Anderson, B.G. : Developmental Disturbances and Malocclusion of the Teeth Produced by Androgen Treatment in the Monkey, (Macaca Mulatta), A.J.O. 40: Jan. 1954.

50. Engel, M.B : Condylar Growth and Mandibular Deformities, Angle Orthodontist XVIII P.133 July Oct. 1948.

51. Engel, M.E, and Brodie, A.G. : Condylar Growth and Mandibular Deformities, Surgery 22: 976- 999, Dec. 1947.

52. Korkhaus, Gustav : Disturbances in the Development of the Upper Jaw and Middle Face, A.J.O. 43 : 848 1957.

Class III Malocclusion.

Angle[1] defined Class III malocclusions as cases in which the body of the mandible and its superimposed dental arch are in mesial relationship to cranial anatomy.

These malocclusions demonstrate a very distinctive facial appearance. Over the last 200 - 300 years, they have been referred to as underhung jaw, inferior prognathism, Hapsburg jaw, mesial occlusion, infraversion, anteversion, prenormal, progenic, macrognathism, mandibular overbite etc,.

Angle taught that the perverted axial forces modified the architectural form of the mandible, and this was widely accepted. He believed that it was remodelled to best resist the new lines of stress from the faulty pairing of the inclined planes of the teeth.

Strang[2] describes how a Class III malocclusion can develop. Primarily, growth disturbances of the rami and body establish a lingual occlusion of the maxillary incisors, and bucco-lingual cusp-to-cusp relation of the buccal teeth. To obtain a shearing action of the buccal inclined planes, the mandible is swung laterally, producing a posterior cross-bite, and disharmony of the centre-line. A perverted swallowing habit is often exhibited. The tongue presses against the mandible, under the incisors, thus tending to narrow the arch and push the mandible forward. The maxillary denture is finally thrown into full lingual occlusion, further restricting maxillary alveolar growth, and increasing mandibular alveolar growth.

Broadbent[3] in his radiographic studies of growth and development studied Class III malocclusion and compared it to normal. He found :-

(1) Forward positioning of the symphysis

(2) Reduction of vertical growth of the ramus, resulting in forward movement of the gonion

(3) Retardation of downward and forward movement of maxilla

(4) No forward displacement of condyles.

The variety found in Class III malocclusions is extremely wide, considering actiology, morphology, chronology, and the location of the condition, according to Stapf[4] who studied the morphology of Class III.

He states that the morphologic types recognised in the literature are

(1) The Contracted and Reduced Palate

(2) The Overdeveloped mandible

(3) Lengthened rami

(4) Lengthened mandibular body

(5) Mesially placed tempero-mandibular articulation,

(6) The phylogenetic pattern

(7) Pathological forms.

Stapf studies cephalometric headplates of 37 patients who had been <u>clinically</u> diagnosed as having Class III malocclusions.

Using the points Bolton, Sella, Nasion, Gonion, Gnathion, and the occlusal and nasal planes, he constructed a mean facial pattern of these Class III cases. He compared this to the normal facial pattern established by Brodie[5] on twentyone individuals eight years of age.

Stapf found that

(1) Class III facial patterns exceeded the normal in height

(2) Class III and normal patterns were similar ~~in~~

(a) Parallel lower borders of mandible

(b) Approximately parallel nasal floors

(c) Constancy of relation of the point Go.

(d) Constancy of relation of the point GN.

(3) Class III and normal patterns were different in

(a) The angle formed by the symphysis and the lower border of the mandible,

(b) The angle of the occlusal plane

The nasal increment was found to be the same percentage of total face height as the normal - 43%. However the mandibular portion of the lower face height was considerably higher than normal and the maxillary portion was less than normal.

Stapf states that there were two theories about Class III malocclusions

(1) Continuation of growth beyond normal limits

(2) An alteration of the normal growth pattern.

He concluded that his study supports the theory of continuation of growth beyond normal limits because of

(1) The regularity of points Go and GN

(2) The parallelism of the lower borders of the mandibles

(3) The almost parallel nasal floors

(4) The constant nasal height between the Class III and normal patterns.

Adams[6] studied a random series of one hundred cases to determine whether variations in mandibular form were associated with specific malocclusions classified according to Angle. He found no significant differences between the mandibles in Class I and Class II cases, but in Class III cases he found

(1) The gonial angle was greater.

(2) The angle at the gnathion was always less

(3) The antero-posterior width of the ramus was significantly less than in Class I or Class II cases

(4) The occlusal plane formed a more acute angle with the lower mandibular border (This is the opposite to the conclusion of other investigators, , and I feel that there may be a confusion in the reporting of the results in Adam's case).

Schoenwetter[7] studied the relation of the upper and lower first permanent molars to the face, in Class III malocclusion. He points out that Angle's classification is based on the relation of the maxillary to the mandibular teeth, with the upper first permanent molar considered as having a rather definite and specific relationship to the facial skeleton and cranium.

Schoenwetter comments on the rather confused picture presented by the literature on the aetiology of Class III malocclusions. Aetiological factors suggested could be grouped as

(1) Habits

(2) Growth Disturbances

(3) Heredity

(4) Endocrine disturbances

Some authors have considered the mandible to be over-developed, others have blamed distortion of the mandible. Other authors have blamed under-development of the maxilla.

Schoenwetter took measurements from before-treatment cephalometric headplates of twentysix cases classified clinically as ClassIII malocclusions. Ages ranged from four to twentynine years.

He concluded

(1) The maxillary first permanent molar is farther forward in relation to the cranial base planes in Class III cases than in Class I and II cases, and this position appears to be rather definite for the class.

(2) The height of the body of the mandible in the molar region is less in Class III malocclusions than in Class I and II cases. However although Schoenwetter measured the distance from the lower first permanent molars to the posterior border of the ramus, he makes no statement about the relative Antero - posterior position of this molar to cranial and facial landmarks.

(3) The height of the symphysis is greater in Class III cases than in Class I and Class II cases.

(4) The angle formed by the occlusal plane to the inferior border of the mandible is greater in Class III cases than in Class I and Class II cases.

Riedel[8] compared the relative antero-posterior position of the maxillary incisors in cases of normal occlusion and the various malocclusions.

In the series studied by Riedel, he found that in normal occlusion the incisor tips were 5.5 - 6.5 mms anterior to the facial plane. In Class III cases, the incisors were found to be "far behind" this point.

In an article on muscular factors relating to malocclusions, Brodie[9] states that due to the malrelation of the skeletal structures in Class III malocclusions, the dental arches present a characteristic appearance. Due to muscular pressure, the maxillary teeth flare outwards and the mandibular teeth lean inwards due to pressure from the buccinator muscle. This is evident both in anterior and posterior teeth.

Dr A.G.Parker[10] states that, clinically, it is possible to divide Class III malocclusions into two types :-

(1) A type where the mandible is overdeveloped with marked spacing between the lower teeth, and the lower incisors are labially placed to the upper incisors

(2) A type where no spacing is evident in the mandibular arch, and where there may even be crowding. Parker concludes that there is no mandibular overdevelopment here.

Parker studied the cephalometric headplates of fortythree children classified clinically as having Class III malocclusions. He also studied headplates of 30 children with Class I jaw relations, but not necessarily having perfect occlusions.

Complete tracings were made of all the headplates, and measurements made to complete a Downs' Analysis. He found that he could divide the Class III cases into four groups,

Group (1) Facial angles exceed Downs normal mean measurements, but mandibular base length shows no significant difference to normal measurements. Parker concludes that in these cases the mandible is mesially placed, and it is in these cases that crowding of the mandibular incisors may be observed clinically. With children aged 10 - 15 years in this group, the "Y - axis" is within normal limits, and the "Angle of Convexity" slightly less than normal. The lower incisors are more lingually inclined than normal.

Group (2) Facial angles are greater than normal, and mandibular base length also exceeds the normal measurements (Downs). Parker states that

(a) this group corresponds with the clinical picture described by Angle and is comprised of those cases seen clinically where the mandible is overdeveloped. However

(b) it does not correspond with the clinical picture described by Strang as there is no increase in the mandibular angle.

Group (3) Facial angles and mandibular angles exceed normal limits. There is no increase in the mandibular base length. "Y- axis" measurements in these three groups are less than normal, demonstrating a more mesial growth of the mandible.

Group (4) Mandibular base lengths and "Y- axis" angles are within normal limits. The angle of convexity is less than normal.

These measurements indicate that the maxilla is distally placed.

Parker concludes that the characteristics associated with Class III malocclusions as outlined by Angle and Strang are all present over the range of cases covered in the first three groups, but are not all present in each individual.

Sanborn[11] (1955) presents a paper on the differences between the facial skeletal patterns of Class III malocclusions and normal occlusion. He points out that conclusions from clinical, craniometric, and cephalometric studies which have been carried out are diverse and confusing.

Sanborn comprehensively reviews the literature. Angle suggested over-development with a more obtuse mandibular angle, or in other cases, a fairly normal mandible with a mesially placed tempero-mandibular articulation.

Dewey (1919) stated that in some cases the premaxilla was underdeveloped. Goddard (1900), Lischer (1912) mentioned an overdeveloped ramus.

Different investigators held that some milder cases were neutrocclusions complicated by linguoversion of the maxillary incisors (Lischer 1912; Hellman, 1931; Moore,1944.)

Lundstrom (1925) called attention to the "Apical base". He felt that in the mandible in Class III cases, the "apical arch" was proportionately larger than the "coronal arch", resulting in the mandibular incisors being lingually inclined.

Like Case (1912) Lundstrom pointed out that in cases of maxillary underdevelopment, the upper denture was retruded and contracted.

Craniometric measurements have been performed by several investigators. Sicher and Krasa (1921) concluded that the variation occurred only in the mandible. Phaff (1923) agreed, but also noted a restriction of the maxillary arch.

Wallace (1927) noted that the distance from the mandibular incisal edges to the mental prominence was abnormally great. He found no significant difference in the distance from the condyle to the mental prominence but stated that the condyles were inclined distally.

Hellman (1939) investigated cephalometrically 25 adult Class III cases and compared them with 62 adult cases with normal occlusion. He found that ramus height could be less than, equal to, or more than that in the normal cases. However, gonion to menton was likely to be shorter, and upper face depth likely to be less than,normal. Lower face depth was likely to be greater than normal.

Bjork (1947) studied cephalometrically 281 Swedish males aged 21 - 23 years. Twentysix had mandibular overbite. He compared these to the whole sample on a basis of mean values. He found

(1) Maxillary base slightly less prognathic than normal

(2) Mandibular base slightly more prognathic than normal

(3) Alveolar changes were of minor significance

(4) A reduction of the "saddle and joint angles" and a shortening of the "vertical part of the cranial base" (sella-articulare). These changes result in a shortening of the cranial base from nasion to articulare and affect the relative positions of the jaws.

Sanborn studied the lateral cephalometric roentgenograms of fortytwo patients aged 15 - 36 years. Twentysix were males and sixteen females. A normal control group was composed of twentysix males and nine females, aged 16 - 38 years who possessed clinically excellent occlusions.

He constructed a geometric figure representing the mean facial pattern of each sample. The Class III pattern was superimposed on that of the normal along the SN line with

(a) Point S registered

(b) Point N registered

To establish the relative prognathism of each jaw, the Angles Frankfort - NA, Frankfort N -Po were recorded.

After studying his measurements, Sanborn divided Class III cases into groups

(A) comprised 45% of the cases studied. The maxilla was within the normal range of prognathism. The mandible was beyond the normal range of prognathism.

(B) (33%) Maxilla below normal range of prognathism, mandible within normal range.

(C) 10% Both maxilla and mandible within the normal range of prognathism.

(D) 10% Maxilla below normal range, mandible beyond normal range of prognathism.

One case presented both maxilla and mandible ~~within~~ below normal range.

In 39 of the 42 cases, the angle NA to Frankfort was less than the normal mean. In 35 cases, the Facial Angle was above the normal mean. The angle NA to Frankfort did not exceed the Facial Angle in any of the Class III cases.

<u>Significant Differences Between the Mean Class III and Control Sample Values.</u>

The maxilla was found to be less prognathous, the mandible more prognathous, the angle of convexity smaller, in the Class III cases than in the control sample.

There was no significant difference in the Saddle Angles (N -S-Art)
The joint angle S-Art-Go, and the angle N-S-Go, and the angle Go-Gn-B, were smaller in Class III than normal.

The Gonial angle, and the Go-Gn- Frankfort Angle were larger in Class III cases.

The upper incisors were more inclined labially, the lower incisors more inclined lingually, in the Class III. The anterior cranial base (S-N) was found to be shorter.

There was no significant difference in the "Y-growth" axis, the ramus length, and the length of the body (Go - GN).

Sanborn points out that these results indicate the mean Class III skeletal patterns, but naturally individual cases vary.

The increased Gonial Angle increases the effective length of the mandible although the mean showed no significant increase in ramus or body length.

Bjork (1947) theorised that

(a) if saddle angle (N-S-Art) became smaller, the tempero-mandibular joint would be displaced forward resulting in increased mandibular prognathism.

(b) a reduction in the joint angle S-Art-Go would also increase prognathism.

Sanborn found no significant difference in saddle angles between Class III and normal facial patterns. However the joint angle (S-Art)go) was found to be significantly smaller in Class III cases. This factor may thus be considered one of the causes of mandibular prognathism in this deformity.

Due to the smaller joint angle, Gonion is positioned farther forward, the ramus forms a more acute angle with the cranial base. Sanborn summarises that the role of the mandible is not mainly one of overgrowth, but of malformation accompanying a poor relation to the cranium and upper face and a strong tendency to middle face deficiency.

This article of Sanborn's is very comprehensive, and assists greatly in clarifying the confused picture of Class III malocclusions.

In an article on disturbances of growth of the upper jaw and middle face, Korkhaus [12] describes various conditions where Class III relation of the jaws is seen. He reports a case of mongolism in a 29-years old man. We see retardation of growth of the upper and middle face, and retruded position of the base of the upper jaw. However, the body of the mandible is well developed. The lower incisors bite one cm. Anteriorly to the uppers - "a true progenia". The tongue shows macroglossia (Korkhaus says that this always accompanies mongolism.

Gosman[13] describes a similar deformity in Mongolism, and states that the facial similarities peculiar to mongolism transcend racial and familial limits. He considers mongolism to be congenital hypopituitarism.

In Turracephaly, Korkhaus presents a case where there is a "false progenia". The middle face and upper jaw are underdeveloped antero-posteriorly and with a normal mandible we see a "false progenia".

A similar facial pattern is seen in Achondroplastic dwarfs. The growth of the base of the skull is retarded, and consequently the upper jaw is under-developed and retruded. The mandible is normally developed and there is a "false progenia".

Korkhaus also shows another rare disease where a Class III relation is seen - Dysostosis Craniofacialis Crouzon.

In discussing genuine Class III (Angle) cases, Korkhaus feels that the overdevelopment of the mandible is accompanied in most cases by an "under-development and backward position of the upper jaw and entire middle face". Korkhaus is not certain whether this underdevelopment is primary, or a secondary characteristic due to the prenormal articulation and abnormal masticatory function. However Korkhaus states " the disturbances in the development of the upper jaw and the middle face are just as reliable a characteristic of true progenia as the excessive growth and alteration in shape of the mandible".

Other endocrine disturbances can produce in Class III malocclusions. Schour and Massler[14] describe the effects of hyperpituitarism. In both juvenile acromegaly and acromegaly Class III malocclusions are present. Hypersecretion of the growth hormone results in overgrowth of those parts in which growth persists in the adult (face, hands and feet). The effect in the face is most marked in the mandible, because of the rapid growth at the condyle, and the overgrowth of the mandible produces the Class III jaw relationship.

Salzmann[15] states that while acromegaly is rare, subclinical acromegaly often occurs, and should be suspected in unexplained progressive separation of the teeth.

Weinmann and Sicher[16] point out that as long as the hyaline cartilage is present on the condyle, its proliferation can be set in motion again by a hyperactive pituitary gland.

Crain[17] deals with the differential diagnosis of Class III malocclusions. He states that of 529 consecutive patients in his practice, 14 had Class III tendencies, 17 were Class III cases and 2 were cases requiring surgical treatment.

In diagnosis, Crain suggests the use of cephalometric X-rays and a study of the morphology, hereditary factors, environmental growth and development, and endocrine influences. If a child presents at age of 8 or more, and a true prognathic condition is suspected, he should be observed for a period and a series of cephalometric X-rays taken. His family history should be examined, and an endocrine analysis and check-up arranged.

Crain feels that a micrognathic maxilla is usually to blame for an initial lingual eruption of maxillary incisors, and of course early correction of the anterior cross-bite is indicated to avoid adverse occlusal and muscle influences.

Treatment of Class III Malocclusions.

It is first necessary to mention pseudo Class III cases, where the maxillary incisors occlude lingually to the mandibular incisors, but the general classification is that of a Class I type, Frequently a deep overbite may be present with this type, whereas in "True" Class III cases, the overbite is shallow or the bite may be open. Due to the incorrect incisor relationship, the mandible is thrust forward in order to occlude the posterior teeth.

In treating these cases the upper incisors must be tipped forward over the lowers. This permits the patient to close into correct occlusion, and the Class III appearance is spontaneously corrected.

In some cases correction of these pseudo Class III cases can be accomplished by the use of a maxillary lingual appliance with finger-springs to tip the incisors labially, or even (in selected cases) of an acrylic bite plane cemented to the lower teeth.

However, if the pseudo Class III has been permitted to persist and resulted in inhibition of maxillary alveolar growth, full banding with Class III inter-maxillary traction may be necessary. These pseudo Class III cases were mentioned by Parker and Salzmann.

Strang states that treatment should be instituted at as early an age as possible, before perverted growth forces have had time to operate. He feels that Class III cases which go untreated show progressive deformity between 14-40 years of age. Cases in which the arch relation is corrected early must remain under observation until after puberty, in case of recurrence. This is particularly true of children who have a hereditary susceptibility to Class III malocclusion.

Strang describes treatment in the deciduous dentition. If the child is seen before the second deciduous molars erupt, a chin cap is worn until the anterior cross bite is corrected. At the same time, the mother is shown how to teach the child correct swallowing exercises. The child is kept under observation after treatment, particularly during the eruption of the second deciduous molars and first permanent molars.

If the second deciduous molars have erupted when the child is first seen, Strang bands the teeth, and uses inter-maxillary traction. Strang outlines treatment procedures in the permanent dentition. For many years, the accepted procedure was to tip the crowns of the mandibular teeth distally until normal inclined plane relationships were established. Then Brodie pointed out that in Class III malocclusions, the mandibular teeth were already tipped distally and lingually, and he suggested that the roots of the mandibular posterior teeth should be moved distally, and the roots of the mandibular incisors should be moved lingually, during treatment.

Strang states that this treatment gave good results, but it was found that relapse occurred.

Strang then adopted the treatment procedure used by Tweed, and this is the method that is generally used. The mandibular teeth are used as anchorage to move the maxillary teeth forward and camouflage the deformity.

Parker concisely summarised treatment of Class III malocclusions. After mentioning the treatment of pseudo Class III cases, he states that treatment of a true Class III case resolves itself into a camouflage treatment in which the upper incisors are moved labially till they are in correct relation to the lower anteriors. Parker believes that the prognosis of these cases depends entirely upon the degree of overbite. Where overdevelopment of the mandible is extreme, and it is impossible to bring the upper teeth into a reasonable relation with the lowers, Parker states that surgical treatment is necessary.

Bkork[18] describes the use of the Andreson appliance in treating mesiocclusions. A spring may be included to assist the labial movement of maxillary incisors.

The case he shows as an example appears to me to be a pseudo Class III type, as the overbite is deep, and the mandible appears to be thrust forward before treatment.

Barrow and Dingman[19] describe surgical treatment for extreme cases of mandibular deformities.

They state that it is usually necessary to mount accurate models on an articulator to determine the shape and size of the bone segments to be removed. A framework is constructed for the mandibular model to enable the parts to be returned to their original positions after sectioning. The mandibular segments are then moved to their most ideal relationship with the maxillary teeth. Extraction of teeth may be necessary.

Dingman sections the body of the mandible, and removes a segment of predetermined size. To avoid damage to the mandibular vessels and nerve, he proceeds in two stages. He first removes the upper half intra-orally, and later uses an extra-oral approach to remove the lower half.

Suggett [20] describes a "pioneering" operation performed in 1930 in a case of "mandibular macrognathia". He prefers this term to "Mandibular prognathism" which is borrowed from anthropology and refers to the facial angle.

Before operation, gnathostatic models, photostatic photographs, and X-rays were studied. The conclusion of the orthodontist and surgeon was that the mandible was definitely overgrown.

At the operation, the ramus was sectioned bilaterally parallel to the occlusal plane, and the jaws ligated together, using previously placed bands. There was a satisfactory occlusal and aesthetic improvement due to the operation.

Clarkson[21] describes surgical techniques. He uses the method developed by Kostecka because it is comparatively simple, leaves minimum scarring and is reliable. The rami are sectioned with a Gigli saw and then the chin displaced backwards by manual pressure. Previously applied cast metal splints are then rigidly fixed together. Clarkson states that prolonged, rigid, accurate post-operative intermaxillary fixation is the key to success. This is to overcome the main objection to this "blind osteotomy" technique - the small area of apposition between the upper fragment which swings forwards and inwards, and the lower fragment which has been pushed back. Ten to twelve weeks of rigid fixation is recommended, sometimes followed by a further period with elastic fixation between the hooks on the splints.

With some severe cases, backward displacement alone does not correct the whole disfigurement, and it may be necessary to resect two to three cms. of the inferior border of the mandible in the region of the symphysis to reduce the excessive vertical depth.

Variations of technique are described in the various text books on oral surgery.

Goldstein[22] presents a good article appraising the results of surgical correction of Class III cases. He states that Hullihen performed a pioneer operation in 1848. Results of succeeding operations ranged from good to the complete loss of the mandible.

In 1898 Blair performed a successful operation. He resected a segment of the body in the bicuspid region, and subsequently used interdental wiring for fixation. Here of course, mandibular nerve and artery are severed.

Babcock in 1910 reported resection by horizontal sectioning of the ramus.

In their appraisal of orthodontic results, Brodie et al[23] found that actual bone changes during orthodontic therapy were restricted to alveolar process, and although adult Class III cases may have satisfactory occlusal relations, aesthetics were not improved markedly.

Goldstein presents seven cases treated by combined orthodontic and surgical means.

Procedure

(1) Complete records for study and consultation with surgeon

(a) Impressions of both jaws and bite record

(b) Lateral head X-rays (at least 5 feet target distance)

(c) Complete intra-oral X-rays

(d) Frontal and lateral photos.

The models are mounted and studied to see

(a) what "shifting" is necessary to reposition the jaws,

(b) What tooth positioning is necessary in each arch to enable a correct occlusion to be achieved.

Goldstein follows these cases and presents X-rays taken several years after each operation. Criteria of success are

(1) A good functional occlusion

(2) Improved aesthetics

(3) Bony union of cut surfaces.

Goldstein's Conclusions.

(1) Adequate pre-operative study to determine

(a) Amount of pre-operative orthodontic treatment needed.

(b) Best type and direction of surgical cut (he likes the condylar cut)

(c) Has growth ceased ?

(2) A rigid multi-band technique necessary to distribute the load of post-op. retention over as many teeth as possible.

(3) Bony union is most rapid where there is

(a) Maximum surface contact

(b) Minimum displacement.

(4) Paresthesia following surgery is usually restricted to lower lip and is transient

(5) Improvement in facial lines is nearly always achieved.

(6) Post-operative orthodontic treatment is usually beneficial

(7) Patients usually very grateful.

R E F E R E N C E S.

1. Angle, E.H. : Malocclusion of the Teeth, S.S.White Coy. 1907.
2. Strang, R.H.W. : A Text Book of Orthodontia, Lea and Febiger 1950.
3. Broadbent, B.H. : A New X-ray Technique and its Application to Orthodontia, Angle Orthodontist 1: 45, 1931.
4. Stapf, William C.: A Cephalometric Roentgenographic Appraisal of the Facial Pattern in Class III Malocclusions, Angle Orthodontist 18 : 20 1948.
5. Brodie, A.G. : On the Growth Pattern of the Human Head from the 3rd month to the Eighth year of Life. American Journal of Anatomy, Mch.1941.
6. Adams, J.W. : Cephalometric Studies on the Form of the Human Mandible, Angle Orthodontist 18 : 8, 1948.
7. Schoenwetter, R.F. : The Relation of the Upper and Lower First Permanent Molars to the Face in Class IIIMalocclusion, Angle Orthodontist XVIII : 16, 1948.
8. Riedel, Richard A. : The Relation of Maxillary Structures to the Cranium in Malocclusion and in Normal Occlusion, Angle Orthodontist, 22 : 142, 1952.
9. Brodie,A.G.: Muscular Forces in the Diagnosis and Treatment of Malocclusion, Angle Orthodontist 23: 71, 1953.
10. Parker,A.G. : Class III Malocclusions, 1956, (Unpublished)
11. Sanborn, R.T. : Difference between the Facial Skeletal Patterns of Class III Malocclusion and Normal Occlusion, Angle Orthodontist 25: 208, 1955.
12. Korkhaus, Gustav : Disturbances in the Development of the Upper Jaw and the Middle Face, A.J.O. : 848, 1957.
13. Gosman, S.D. : Facial Development in Mongolism, A.J.O. 37: 332, 1951
14. Schour and Massler : Endocrines and Dentistry. J.A.D.A. 30 : 595, 1943.
15. Salzmann,J.A. : Orthodontics, Principles and Prevention, J.B.Lippincott, 1957.

16. Weinmann and Sicher, : Bone and Bones. 1955.

17. Crain, Solon P. : The Comprehension of Diagnostic Differentiation of Class III cases for the Institution of Treatmdnt Therapeutics, A.J.O. 41 :604,1955.

18. Bjork, Arne : The Principle of the Andreason Method of Orthodontic Treatment, a Discussion Based on Cephalometric X-ray Analysis of Treated Cases, A.J.O. 37 : 43, 1951.

19. Barrow, G.V. : Dingman, Reed,O : Orthodontic Considerations in the Surgical Management of Developmental Deformities of the Mandible, A.J.O. 36: 121, 1950.

20. Suggett, Allen H.: The Correction of a Mandibular Macrognathia by Surgical Means, A.J.O. 30 : 911, 1953.

21. Clarkson, Patrick : Textbook of Functional Jaw Orthopaedics, Henry Kimpton,1952.

22. Goldstein,A : Appraisal of Results of Surgical Correction of Class III Malocclusions, Angle Orthodontist XVII : 59, 1947

23. Brodie,A.G, Downs,W.B., Goldstein,A., and Meyer,E : A Cephalometric Appraisal of Orthodontic Results. Angle Orthodontist, 8 : 1938.