STANDARDISED RADIOGRAPHY

in

ORTHODONTIC CASE ANALYSIS

An investigation of Incisor Axis — Mandibular border angle, and Gonial angle in relation to Malocclusion; Also the chin point — incisor distance in relation to age and malocclusion.

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Presented for Degree of Doctor of Dental Science

University of Sydney, Nov. 1945
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PREFACE

The material for the present investigation has been collected during the last five years in the routine of private orthodontic practice.

Apart from the fact that no other facilities are yet available for standardised radiographic surveys, it was considered of great value that most of the patients examined have received orthodontic treatment and the classifications recorded have been confirmed or modified by observation over a long period.

Previous research in the same field has been carefully examined and referred to in the earlier sections, and, where satisfactory, has been briefly quoted, the aim being to avoid needless repetition. Full bibliographies have been included at the end of each section for convenience.

The material examined consists entirely of cases of malocclusion. Tracings of normal cases published by Dr. Brodie have been included to illustrate normal conditions. Care has been exercised to give full credit where any illustration is not the writer's own work.

Acknowledgements are due to those who shared in the compilation of the thesis:

Mr. Clifford for photographic reproductions
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W.N. BENSON, M.D.S. (Syd.)
INTRODUCTION

The treatment of malocclusion can only be successful if based on a correct diagnosis. A thorough appreciation of the characteristics of normal occlusion at all growth stages is essential if early deviations are to be detected.

No area has yet been located in the face or head, sufficiently stable in growth to serve as a basis for judging the normality of the denture. With each advance in the knowledge of the growth and development of the jaws and teeth comes an increased conviction that such a solution to the problem will never be found.

Normal occlusion admits of such a wide range of variation in all the related parts that any mathematical statement is out of the question. Normal occlusion is individual and is the result of harmonious growth and development of all the parts—teeth, supporting bone and musculature.

Each case of malocclusion must be regarded as a growth problem to be unravelled if possible and the perverted growth forces guided back into the channels from which they have deviated.

Brash, in 1924, referring to the "Modes of growth" of the jaws anticipated the use of X-rays—"The ideal method would be to follow the stages of growth in the skulls of the same individuals at different ages, but the time has not yet come when X-rays may enable us to determine accurately the sites of the small differences that mark successive stages." (J.C. Brash "Growth of the Jaws" Page 30)

The present paper has as its object the description of the technique for producing standardised lateral radiographs of the skull and the method of obtaining data from these films to contribute to the analysis of malocclusion.

An investigation has been carried out to determine the relation between the class of malocclusion and the mandibular incisor angle and the gonial angle; also the mandibular angle and gonial angle have been examined to find if any correlation exists between them.

It is considered that this investigation supports the contention that serial standardised radiographs are of great benefit in determining the growth trends, and their routine application to orthodontic practice opens a wide field for the clinician as well as the research worker.
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Historical Introduction

Within the last two decades investigators in the field of skeletal growth have had the advantage of roentgenography, making possible accurate serial observations of living subjects during the active growth period.

The accuracy of this method over that of anthropometric measurements has been amply substantiated. (1)

The development of a special roentgenographic cephalometer by Broadbent (2) in 1931 marked the beginning of a new era in the search for knowledge of growth processes in the cranium and related structures. The results of investigation carried on since have been published from time to time and have materially added to our knowledge, in some cases correcting errors in our conceptions of growth and development.

In 1932 the Graduate Research Board of the University of Illinois installed a similar apparatus in the Department of Graduate Orthodontia, under the charge of Dr. A. G. Brodie (1) who has conducted numerous investigations greatly enriching orthodontic literature.

While the accuracy of these instruments is essential, where minute growth changes in serial readings must be recorded, the cost and space for housing, renders them unsuitable for clinical purposes.

L. B. Higley (3) in 1936 published details of an instrument designed to overcome these difficulties. In the same year G. Vernon Fisk (4) described and illustrated a very much simplified equipment.

Also in 1936 E. M. Griffin and Meyer Hoffman (5) of Brooklyn N.Y. designed a rather elaborate instrument along the same lines as that of Broadbent; while aiming at adaptability to clinical practice.

Korkhaus (6) in Bonn, Germany was using some method of head fixation for his telerontgenograms, about this time. L de Coster (7) of Brussels made use of teleradiographs, but apparently used no special instrument for fixation.

Margolis (8) (10) (11) in 1939-41 recorded his work with a simplified cephalostat and also described his method of tracing the films.
McDowell (12) in 1941 published results of investigations carried out at the Child Research Council and University of Colorado School of Medicine. The design of the equipment was made in association with Charles M. Waldo (12) and is quite suitable to office practice.

It is apparent from the widespread use of radiography in the practice of orthodontics and in the field of research in growth, that the method holds out possibilities above any previously at our disposal.

The years to come will, no doubt, find a much wider application of standardised radiographs to the clinical practice of orthodontics.
DESCRIPTION OF INSTRUMENT

The requirements of an instrument suitable to clinical practice are:-

(1) A high degree of accuracy

(2) Sufficient compactness to be housed in the average orthodontic office

(3) Ease of manipulation

(4) Reasonable cost of production

The writer designed the instrument used in these investigations in 1940 in collaboration with an engineer who carried out its construction.

The cephalostat consists of two bakelite ear posts (D) fixed to blocks, housed in a box with a central shaft having right and left hand threads to allow approximation of the posts on turning the threaded shaft. (C,E)

The whole unit can be rotated around a vertical axis for the taking of antero-posterior radiographs, or any other special angulation. (A,B)

The main upright is bolted to the floor. The horizontal arm carries the film holder (F,H) which can be adjusted to approximate the patient. The film holder can be rotated about a vertical axis and the individual grips (H) can be adjusted in the vertical to adapt cassettes of any size; while an adjustment is also possible to alter the cassette angle in the vertical plane. An adjustable pointer (G) is provided to orientate the head in the vertical plane.

The X-ray head is held in position by a rod attached to the wall. After removing the cone, the ring is locked in position firmly.

Target-film distance is four feet and the central ray from the tube passes through the two ear points for lateral exposures and midway between these points for antero-posterior views.

Care was taken that the result would be as accurate as possible. An adjustment was allowed, to rotate the ring for fixation of the X-ray head, so that correct angulation would ensure an horizontal beam.
Having tested the accuracy by several exposures and carried out minor corrections, the adjustment of the equipment can be checked on each film by noting the imposition of the ear posts.

The reliability of the instrument is considered satisfactory by the accuracy of consecutive films the tracings of which have been superimposed.

The patient is seated on a pump chair and raised until the external auditory meati are on the level of the ear posts. The screw E is turned to approximate the points, which are passed into the meati.

Firm pressure without discomfort limits the depth of insertion. A marker attached to the ear post gives a reading on a calibration, which can be recorded for each patient as a guide for future exposures.

It has been found, that the patient is in a more relaxed and comfortable position, with the head orientated with the plane auricular-anterior nasal spine, horizontal. Many seem to favour the Frankfurt Horizontal as the plane for this orientation, but it often results in the chin being forced down and the proximity of the vertebrae often interferes with the clear outline of the posterior ramus and gonial angle.

The pointer (G) is adjusted to touch the skin surface immediately below the nose, and the head rest placed in contact with the occiput. Having corrected the position of the cassette it is now advanced to the point of contact with the ear post, and locked securely in place by means of the clamps (F).

After the X-ray head is fixed in place and the angulation checked by the calibrations, the exposure can be made.

It is not considered necessary to record the exposure times or the processing of films as these matters can be found in textbooks on the subject, and vary with the type of machine in use.

**Tracing of Films**

Several methods of obtaining an accurate tracing of relevant matter from the films were attempted. It has been found that a special tracing material made by Eastman Kodak known as "Kodotrace" gives the best results.

It consists of a silk material with a clear emulsion surface on one side. Transparency is almost perfect and the silk surface takes either pencil or ink readily.
Almost any number of these tracings can be superimposed without noticeably interfering with the transparency.

The technique for making the tracings has been amply recorded in writings of Broadbent, Brodie and McDowell \(1, 2, 12\). It is sufficient here to state a few principles which have been followed in this investigation.

There is no difficulty in locating points in the mid-sagittal plane of the head, such as Nasion, Gnathion, Sella Turcica, \textit{etc.}, as only one image appears. Where two images of bilateral structures such as the angle of the mandible are seen on the film, it indicates the unavoidable error due to the varying distance between object and film surface; or it may mean a bilateral asymmetry which in some degree is almost always present. Following McDowell it has invariably been the procedure here to bisect the distance between shadows when making a tracing of the mandible.

It will be noted that in a lateral radiograph the condyle head is obscured by the density of the temporal bone.

While the procedure has not been followed in all the cases recorded, it is now the practice to replace the cassette after the lateral exposure and with the patient still in position make an exposure with the mandible in the extreme caudal position. Opening the mouth throws the condyle head forward and below the eminentia articularis, where no bone structures obscure the outline in a lateral exposure.

The condyle can then be traced from this second film and transferred to the first giving an accurate tracing of the whole mandible.

Angles have been measured directly on the tracings with a protractor.

Brodie has compiled corrected readings for his instrument which enable him to arrive accurately at linear measurements, in spite of varying distances between object and film in different patients. This is obviously necessary for linear measurement but does not apply in observations of angles between various structures and planes.
The lateral standardised radiograph in centric occlusion.

Note the superimposition of the ear rods, the test of accurate adjustment of the equipment.
This figure shows the tracing used to gain the information for this investigation, made on "Kodatrace" stapled to the film.

The line SN is used for the superimposition of successive radiographs for the same individual.
Fig. 6.

The tracing on the Kodatrace is reproduced here.

Note the posterior and the inferior border tangents, the incisor axis, and the method of determining the incisor apex--chin point distance.

Angles are measured directly on the tracing with a protractor.
Figs. 7, 8 and 9 are included to illustrate the method, (not used for all cases in this work) of obtaining an unobstructed picture of the condyle head.
Fig. 8 taken with the patient in the head positioner, with the mouth open widely, reveals a clear image of the condyle head, the tracing of which can be transferred to the main tracing as shown in Fig. 9.
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<th>No.</th>
<th>Author(s)</th>
<th>Title</th>
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<td>1</td>
<td>Brodie, Allan G.</td>
<td>Observations of the Growth of the Face</td>
<td>American Journal of Orth. and O.S., Vol.25, P743, 1940</td>
</tr>
<tr>
<td>2</td>
<td>Broadbent, Holly</td>
<td>A new X-ray Technique and its Application to Orthodontia</td>
<td>Angle Orthodontist P45, 1931</td>
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<td></td>
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<td>7</td>
<td>De Coster, L.</td>
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<td>I.J. of O. and O.S., Vol.22, P912, 1936</td>
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<td>8</td>
<td>Hooten, E.A. &amp;</td>
<td>Plastic and Graphic Technique for Recording Dental Changes and Facial Growth</td>
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<td></td>
<td>Margolis, H.I.</td>
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<tr>
<td>12</td>
<td>McDowell, R.M.</td>
<td>Use of Lateral Head Radiographs for Evaluating Orthodontic Results as Distinguished from Growth Changes</td>
<td>A.J. of O. and O.S., Vol.27, P59, 1941</td>
</tr>
</tbody>
</table>
GROWTH OF THE JAWS

"All nurtural factors must primarily be considered as the complement of the inheritance; and it must not be overlooked that physiological factors which may appear to condition and to control the growth of the jaws may themselves be the expression of the genetic constitution."

(Brash)

The degree of growth ultimately attained is the expression of the combined influences of (1) inheritance (2) prenatal conditions and (3) post natal environment.

Without entering the field of etiology which is not in the scope of the present thesis, it is necessary to preface the discussion of the growth of the jaws with the generally accepted conception of the individual limitation to growth potential.

It seems incorrect or at least inaccurate to speak of "inherited abnormalities".

Individual characteristics, within the range of normalcy, are widely variable; but the harmony of related parts agree with our conception of the normal. These individual variations are brought about by variations in the relative rates of growth of the associated parts; and these rates of growth would appear to be inherited and account for the occurrence of family likenesses.

Hence it may be more correct to refer to "inherited disharmony in the relative rates of growth" in those cases where abnormality appears in successive generations.

Alexander Sved quoting the work of Hurl Jansen, states "The development of the offspring proceeds according to the characteristics contained in the fertilized ovum, and the characteristics responsible for the reproduction of the kind are inherited. The resemblance of a child to its parents is brought about by a more specific inheritance. Within the same species, generally, there is a closer resemblance of the offspring to the parent than to other members of the same species. But since we have already shown that resemblance means similarity, and similarity can be expressed only in terms of proportionality, we must conclude that the relative rates of growth of the future individual are already determined in the fertilized egg cell, and for this reason they are inherited."
Fig. 13.—Progress of growth of anterior facial height in three cases selected at random.
Thus every individual begins life with an inheritance, which does not necessarily mean that the abnormalities of the parent will be transmitted to the offspring, but that the offspring is endowed by the parents with certain growth characteristics, which are entirely individual.

Thus, from a theoretical point of view, an individual may begin life with an inherited tendency to normality or with an inherited tendency to abnormality. During development these tendencies may be modified by injurious influences, so that under all conditions of inheritance an abnormality may develop."

From the foregoing quotation it will be agreed that the ultimate form of the bones will basically compare with an inherited pattern, modified by possible injurious influences during the developmental period.

Interpretation of growth changes in the face and head, revealed by successive standardised radiographs, led Brodie to state that parallelism in the form of increments was a marked tendency. Any point studied closely followed a straight line when tracings of radiographs were superimposed on a given area in the base of the skull.

The obvious conclusion supported by the work of McDowell and Hellman was that "the individual morphogenetic growth pattern of the skull tends to establish itself early in the life of the individual child." According to Brodie's data the growth pattern can be said to stabilise about three months of age, from which point the growth increments follow straight lines if normal growth proceeds. This is clearly illustrated by the accompanying diagram from Brodie. (Fig. 10)

Because of its comparative simplicity and isolated location more is known of the growth changes in the mandible than in the other bones of the face. The form and relative degree of development can be assessed with greater accuracy and lends itself to clinical appraisal.

Brodie has established the fact that the form of the mandible is stabilised at an early age and growth increments do not (if growth is normal) interfere with that form, once established. The gonial angle was stated to remain the same throughout growth which Hellman had hinted some years before. This fact will be further and more fully discussed later.

The present thesis suggests that the mandible is of basic importance in pretreatment analysis of malocclusion for the following reasons:

(1) The early stabilisation of the growth pattern and its anatomical simplicity.
(2) The comparative ease of assessing the degree of growth at a given stage.

(3) The definite limitation to treatment imposed by the form and degree of growth of the mandible.

The work of Brash, Broadbent, Brodie, Hellman, McDowell inter alia, will be freely drawn on to cull relevant material in the following discussion of the growth and development of the jaws and teeth. It is not suggested that an exhaustive review of this wide subject is necessary; interest will centre around the growth of the mandible and only relevant matter beyond this will be mentioned to establish the premise.
GROWTH OF THE MANDIBLE

About the fortieth day of intra-uterine life the mandible begins to ossify in the membranous tissue lateral to Meckel's cartilage. Very little of Meckel's cartilage directly contributes to the formation of the mandible, the most medial part only, being ossified.

As early as the third month the mandible has assumed its characteristic form. The right and left sides are joined in the midline of fibrocartilage which is replaced by bone about the end of the first year of post natal life.

While the symphysial fibrocartilage persists, it is an active growth centre and brings about some increase in width and length of the mandible. Brash (1) agreeing with the findings of Kolliker states "This seems to suggest that there is more in the region of the symphysis than mere antero-posterior thickening of the jaw; that there may be in fact a certain amount of growth forward at the anterior end even in the human jaw".

It is of great importance to appreciate the location of growth increments which result in the downward and forward growth of the mandible during the period from birth to maturity. Increase is brought about by a combination of surface deposition and absorption. By the method of madder feeding Brash has indicated these areas of active deposition with the synchronising absorption process, resulting in the increase of the mandible consistent with functional demands.

Lateral increase is brought about by surface deposition on the outer aspect while medially absorption keeps the thickness of the jaws within normal limits. Surface modelling to meet the requirement of muscle activity is constantly taking place not only during the developmental period but throughout life.

The two directions of growth of greatest interest to us, in our present investigation, are vertical and antero-posterior which together give a resultant downward and forward growth in relation to the comparatively stable cranial-base area.

Vertical Growth

The vertical height of the body of the mandible in fetal and early post natal life is brought about by additions to the lower border and increase at the alveolar crest. By far the greatest contribution to body height is made at the alveolar margin. At the same time the area at the condyle
and also the coronoid process, are actively proliferating and as the condylar process is in relation to an area which may be regarded as fixed, the deposition of new bone carries the mandible away from the temporal bone in a downward direction.

Brodie (2) has shown that the growth of the temporal bone results in the lowering of the mandible during the first five years of life, thus contributing to the increase in vertical height of the face.

Active proliferation at the condyle head continues to an age of twenty to twenty five years. The vertical height of the ramus is closely connected with the normal eruption of the teeth and must persist until the third molars are in place.

Antero-posterior Growth

Deposition of new bone takes place along the posterior border of the ramus and concurrently a resorption process removes bone on the anterior border. The result is the increase in distance from incisor alveolar border to the anterior border of the ramus, providing space for the developing dentition.

Considered together the increase in ramus length and the increments to the posterior border of the ramus, the resultant effect is a downward and forward displacement of the body of the mandible. As stated by Orban (2) "During the period of growth in the condylar region the condylar surface which is in contact with the mandibular fossa of the temporal bone, is a relatively fixed point. The mandible moves, therefore, away from this point downward and forward. The plane of movement of any point, e.g. the chin point is parallel to the plane of the condylar growth."

Brodie maintains that throughout normal growth the angle between ramus and body is stable, previous assertions that the angle becomes more acute as maturity is approached, not being upheld by recent observations. This matter will be discussed later in detail.

Growth of Alveolar Process and Eruption of the Teeth

Alveolar bone, while not differing from bone elsewhere, is tissue developed for the specific function of supporting the teeth. In the absence of teeth the process fails to develop and after the loss of teeth resorption occurs.

The alveolar bone proper or inner cortical plate is a highly specialised tissue upon which depends the normal attachment of the tooth by means of periodontal fibres. For normal health of periodontal and gingival tissues the correct degree of calcification of this cortical plate is essential, both during
Main sites of bone deposition (red) and resorption (green) associated with downward and forward growth of the mandible.

(A) Condyle upward and backward resulting in downward and forward movement of the mandible.

(B) Posterior border of mandible carrying the mandible forward.

(C) Alveolar process growing in harmony with ramus length.

Surface deposition on mandibular border is negligible.
the developmental period and during the years of function.

Brash (1) stated:— "It would appear, therefore, that while the alveolar bone owes its development and continued existence to the teeth, yet it is subject to the same growth influences as those which govern the supporting parts of the jaws and that its extent and consequently its general arrangement depend not upon the teeth, but upon the jaws themselves."

Relation of Gum Pads at Birth

Observation of a number of new born infants by Lilah Clinch (5) led to the conclusion that a wide variation in the relation of the gum pads existed; and while an attempt was made to classify them and correlate them with consequent growth and probably final outcome, the conclusions were not wholly satisfying. Sillman (6) later disagreed, mainly on the ground that the physiologic rest position of the mandible had not been taken into consideration but all had been based on centric occlusion.

Clinch regarded a space anteriorly between the gum pads as normal and the absence of it indicative of a developing deep overbite. On the contrary Gottlieb regards complete contact the normal condition and vertical height is achieved by the eruptive force of the teeth wedging the jaws apart. Sillman saw no relation between space anteriorly in gum pads and subsequent overbite in his series of models of developing children.

Development of Vertical Height

Hellman (7) in discussing the development of vertical height in the jaws, writes, "with the appearance of the dentition there is a sort of wedging apart of the maxilla from the mandible. The increase in the dimension of height is thus brought about not only by the vertical growth of the face, but also by the addition of the combined height of the crowns of the teeth separating the two jaws."

There seems to be a sharp difference of opinion as to the direct cause of the increase in dental height which occurs concurrently with the eruption of the teeth.

In his book on "Biology and Pathology of the Tooth" Gottlieb (8) affirms that the first teeth to erupt immediately occlude, and their continued eruption results in the gradual separation of the edentulous ridges. After eruption and occlusion of the first deciduous molars the process of eruption continues, increasing the vertical height.
Hoses Diamond (9) in an editor's note of these remarks of Gottlieb and Orban, stated "This evidence clearly indicates the part the erupting teeth play in elevating the occlusal plane or increasing the inter-maxillary space. It is necessary to emphasize the fact that in the pre-eruptive stage an occlusal plane is already established by the edentulous jaws and that as the teeth erupt the occlusal plane is elevated and with each succeeding pair of erupting teeth, the intermaxillary space is further increased."

Schour and Hassler make the same statement:
"Normally, the vertical height of the jaws and the length of the arch are increased by the eruption of the teeth."

Diamond as a result of further observations has been led to reject this theory that the eruptive force of the teeth is the primary cause of increased vertical height of the jaws. (10)

"I realise that this touches a controversial aspect, but I still affirm that the growth of the jaws in no way influences or interferes with the growth and development of the teeth, and that the growth and development of the teeth in no way influences the growth of the jaws. Their interrelationship is spatial. If the jawbones do not grow normally and are retarded, the teeth will still develop and grow normally, but will lack the needed room for their proper positioning. With comparatively few exceptions, the teeth will even erupt—in any position, labially, lingually—unless there is a definite mechanical obstruction to prevent the eruption mechanism; and then such isolated teeth will remain impacted within the jaw. But even in these cases, their completed growth and development is not interfered with."

Eruption of the Teeth

Kurt Thoma (12) in a review on "the factors controlling Development of Mandible and Maxilla, cites a number of reported cases of anodontia in which the growth of the jaws had been relatively normal. The absence of teeth had not interfered with the growth to any great extent; hence whatever influence the eruption of the teeth may have on the jaws it is not primary but at most contributory.

The many theories of tooth eruption need not here be mentioned in detail as a statement of positive evidence available renders many of them immediately untenable. However the table reproduced from the article by Hassler and Schour (13) will serve to recall the main attempt to explain the confusing problem of tooth eruption. (Fig. 12)
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THEORIES OF ERUPTION

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<td>3. Growth of periodontal tissues:</td>
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<td>Movement of soft tissues surrounding tooth pulls the latter into oral cavity</td>
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<td>A. Growth of and pull by periodontal membrane</td>
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<td>B. Growth of alveolar bone</td>
<td>Brash</td>
<td>Growth of alveolar bone carries or pushes the tooth into the oral cavity</td>
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<td>6. Pressure from cellular proliferation</td>
<td>Eidmann</td>
<td>Osmotic pressure or tissue tension resulting from (1) proliferation of cells, (2) vascular bed, or (3) both, in the pulp and periapical tissues pushes tooth into oral and cavity, the roof of the bony crypt being resorbed by pressure atrophy</td>
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<td>Aichel</td>
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<td>Oehrleins</td>
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<td>von Korff</td>
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<td>7. Pressure from vascular bed in</td>
<td>Constant</td>
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<td>A. Pulp</td>
<td>Leist</td>
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<td>B. Periapical tissues</td>
<td>Fischer</td>
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<td>King</td>
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<td>Baume (medullary theory)</td>
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Fig 12
(Massler + Schour).
Alveolar growth distinct from tooth eruption, elevating occlusal plane.

--- elevation subsequent to completion of root formation.

Mandibular 1st Permanent Molar
Minimum degree of elevation

Mand. border.

Lower Canine
Maximum degree of elevation

Mand. border.

Lower Central

Mand. border.


Fig 13.
The conclusion reached favours the theory of vascularity of the periapical tissues, though not to the exclusion of "other factors or theories as supplementary agents or sources of the eruptive force."

Cephalometric roentgenology has made possible the accurate recording of tooth changes during the developmental period of the one subject eliminating the necessity for many observations of a large series at all age levels. Using the files of the Bolton Study, Western Reserve University and the files of the Department of Orthodontia, University of Illinois, Harry Carlson (14) traced the movement of the teeth in their eruption. The distance from the lower border of the mandible, (which was used as a basis for measurement) was shown steadily to increase.

From the commencement of calcification the crown formation was completed without much change in distance between apex of tooth and mandibular border. When the root formation began there was some tendency, particularly noticeable in canines, for a downward movement of the developing tooth. This change just precedes a rapid movement away from the border of the mandible. From this stage on the distance between apex of the developing and erupting tooth and the border of the mandible becomes virtually constant; in other words the cemento-enamel junction at the beginning of eruption occupies approximately the same position relative to the border of the mandible as the apex of the fully developed tooth.

However it is evident that a bodily upward movement of the whole alveolar process also takes place as Brash has shown, the degree varying in different tooth areas and most marked in the canine region. This bone growth must be regarded as distinct though of course synchronizing with tooth eruption.

The occlusal plane is seen steadily to rise, the whole tooth being carried further from the mandibular border. We are assured from the experiments of Brash and Bassler that this is not due to additions on the border of the mandible, but to an increase of the alveolar process.

The minimal degree of this bodily elevation of the teeth is in the molar region while anteriorly the greatest increase occurs. This is to be expected on account of the obtusity of the gonial angle which results in greater vertical height anteriorly as the body of the mandible develops forward.

In the illustration (Fig. 13) the distance traversed by the developing canine is greater because of the characteristic downward movement of the tooth just prior to the commencement of root formation. Why and how this takes place is not known.

This elevation continues at least until ramus growth
ceases which is not until the third decade of life.

The bone changes seen in sections of an erupting tooth are exactly comparable with the tissue changes demonstrated when teeth are moved orthodontically. "The trabeculae of bone, bordering on the periodontal membrane are arranged in the direction of eruption. The individual trabeculae are bordered on the side facing the tooth surfaces with a calcium-free margin against which osteoblasts can be seen. The induced tension precipitated by the act of eruption was transmitted from the cementum to the periodontal connective tissue and probably stimulated the formation of bone." (15)

The movement of the tooth crown occlusally must exceed the growth of alveolar bone and hence we have the picture of bone trabeculae directed occlusally at this stage. It would seem to indicate that bone growth is not the primary factor bringing about eruption. Nor would one conclude the bone trabeculae laid down at the fundus a cause, but rather a result of occlusal movement of the developing tooth. (16)

The number of these layers of bone at the fundus varies in different teeth being least in the molars where bodily movement of the tooth during eruption is at a minimum.

The theory of vascularity of periapical tissues seems to be consistent with the histological picture given by Gottlieb of the differentiation of the dental sac at the fundus to form what Sichler (17) terms the "cushioned hammock ligament."

Probably the increased vascularity at the fundus is the main source of the force, which acting against the "cushioned hammock ligament", and in the absence of any abnormal opposing force, brings about the occlusal movement of the tooth. The alveolar bone growth synchronises with the eruption of the teeth and becomes adapted to the functional requirements of the tooth as it emerges into the mouth. The alveolar bone is subservient to the tooth. (15)

It is a matter of clinical observation that very slight obstruction can interfere with normal tooth eruption. Lack of space into which to erupt, will halt the process and root formation will continue more deeply into the body of the jaw.

With this evidence before us, it would appear that the eruptive force of the teeth is not of sufficient intensity to be a factor in increasing the vertical height of the jaws, and alternative explanations must be sought.
Diamond (18) has produced evidence which shows that the increase in vertical height and the appearance of space between the edentulous ridges, precedes the clinical eruption of the tooth. The growth in ramus length was considered the primary factor in increasing this dimension and made possible the unrestricted eruption of the teeth. "There is no direct cause and effect relation between the growth and development of the jaws and the growth and development of the teeth. There is a factor of spatial inter-relation between the growth of the jaws and the clinical eruption of the teeth." (18)

Teeth will individually develop even when jaw growth to accommodate them is inadequate, and obstruction to their eruption may cause their retention in the jaw bone. For normal development of the dentition, there must be an accurate synchronisation of periods of growth acceleration and retardation.

Ramus length exerts the most profound effect upon the developing occlusion. Probably the degree of growth in no other single dimension can influence so markedly the occlusal relations of the teeth.

Diamond (18) again says:
"Lack of growth in ramus length will produce a characteristic series of growth disturbances:
(a) The intermaxillary space fails to increase.
(b) The teeth cannot erupt and remain submerged, their roots growing normally but deeper within the jawbone.
(c) The vertical dimensions of the maxilla and of the body of the mandible fail to increase.
(d) The anterior teeth continue in eruption resulting in an overbite relation.
(e) The anterior overbite relation will inhibit the forward growth of the anterior part of the mandible."

From the data advanced it appears the ramus length growth precedes the alveolar bone growth and the eruption of the teeth. The timing of this period of accelerated growth must synchronise with the eruptive movement of the teeth if normal proportions are to be maintained. However it is possible that ramus growth may be normal and the subsequent alveolar growth fail; resulting in a deficiency in the vertical dimension associated with a decrease in the gonial angle.

Conclusion

Normal development of the mandible results from accurate timing of phases of acceleration and retardation of inter-related structures, in the absence of any internal or external injurious influence.
The growth of the jaws is directed to the proper functional orientation of the teeth, and is not dependent on the developing teeth for the growth stimulus.

Crowding of the teeth is evidence of failure of bone growth either in direction, degree or chronologic occurrence.
| 5  | Clinch, Lilah | American J. of Orthodontia 30:590, Nov. 1944 |
THE PRETREATMENT ANALYSIS OF MALOCCLUSION

History

It is not necessary for present purposes to recall attempts to analyse or classify malocclusion earlier than the end of last century.

C. F. Delabarre (1829), Carabelli (1848), Kingsley (1872), Magitot (1877) and Talbot (1888) to mention a few of the outstanding names, endeavoured, with the available knowledge to unravel the problem of malocclusion and segregate cases according to type or severity to simplify the approach to treatment.

However none was able to produce a basis for case segregation until Angle presented his epoch marking classification of malocclusion to the profession. Angle stressed the importance of the integrity of the denture and carefully described the normal relation of occlusal surface of the teeth. His idealistic approach to the subject has left an abiding effect on the practice of orthodontics, and none can regard the extraction of teeth as a procedure to be lightly adopted, who has felt the influence of the teaching of Dr. Angle.

With treatment obviously in mind, "the mesiodistal relations of the teeth, dental arches and jaws, which depend primarily upon the positions mesiodistally assumed by the first permanent molars on their erupting and locking", were chosen as the basis for a working classification. Angle further held that in almost all cases the maxillary first permanent molars assumed their normal position mesio-distally on eruption. The occlusal relations of the teeth then became the sign of mandibular mesiodistal deviations, and allowed of the allocation of all cases into one of three main classes.

Class I included all cases with normal mesio-distal relation of the mandibular arch to the cranial structures as indicated by a normal relation of the occlusal surfaces of the teeth, particularly the first permanent molars.

Class II included those cases with the mandibular arch distal to its normal relation to the cranial structure as indicated by the abnormal mesio-distal relation of the first permanent molars. This group was further divided according to labio-lingual axial perversion of the upper anterior teeth, those showing protrusion being styled Class II, div. 1; while those with retruding upper anterior teeth were designated Class II div. 2.

Class III included all cases in which the mandibular
arch was mesial to the normal cranial relation as indicated by abnormal occlusal relations of the teeth, particularly the first permanent molars.

Angle by no means ignored facial harmony and balance but allowed his artistic appreciation, to confirm or modify his classification based on intra-oral examination. The simplicity of the classification at once assured its wide acceptance and treatment, on the whole seemed to testify its fundamental correctness. There has been no doubt that the basis of mesio-distal deviation in denture relations, is a sound basis for pretreatment analysis.

Critics soon arose to reveal the weakness in the classification. Practice failed to justify the dogma of upper first permanent molar constancy. Was this tooth sufficiently stable in its mesio-distal position, to be used as a landmark, in judging mandibular-cranial relations?

The possibility of mesial drifting of the maxillary teeth was raised, resulting in occlusal disturbances simulating Angle’s Class II but requiring very different treatment to restore balance. Also it was argued that the mandibular arch could assume a mesial relation due to drifting and produce a double protrusion. Dr. Grieve has for many years maintained that most cases of malocclusion are complicated by, if not caused by mesial drifting of the teeth.

Dr. Angle, striving always for the ideal, resisted the thought of loss of teeth as a part of treatment, claiming that the basal structures if underdeveloped, would assume their normal dimensions if normal occlusal relations, providing normal function, could be restored. Axel Lundstrom challenged this statement, maintaining that treatment was definitely limited by the degree of growth of the apical base.

The possibility of mesial drifting of the dental units and the failure to influence the basal structures by orthodontic therapy, have together disturbed the simplicity of Angle’s pretreatment classification.

Paul Simon of Berlin originated a technique known as “gnathostatics”, to relate the denture in three dimensions of space and compare readings with compiled average norms. Basically the system departed from the Angle ideal, and made the average the accepted concept of normal occlusion.

To judge antero-posterior deviations of the denture Simon chose arbitrarily the orbitale plane, which was found to pass through the cusp of the maxillary canine tooth in the majority of cases of normal occlusion.
Intraoral signs, such as "key ridge" relation and axial inclination of teeth especially the canines have been used, together with an appreciation of facial harmony and balance, to arrive at a decision regarding the antero-posterior relation of the denture.

At the present time, it is generally conceded that a denture placed too far mesially in relation to basal structures is in an unstable position; balance must be restored by placing the dental units directly over the supporting bone. This procedure, usually ensures the best possible esthetic result, and so may well be the main aim of treatment.

The functional approach to the problem has been crystallised in recent years by the work of Tweed. By dividing the plaster casts in the mid-sagittal plane, Tweed was able to determine the relation of tooth to supporting alveolar process. His claim that the lower anterior teeth must bear a definite relation to the lower border of the mandible and be placed directly above the basal bone support, has been accepted as a criterion of normal balance.

Standardised radiography has greatly simplified the obtaining of relevant data to determine the antero-posterior relation of the dentures. "Key Ridge" relations, and axial positioning of the teeth, particularly the lower anteriors, can be readily and accurately obtained. Also, it is possible to gain some appreciation of the condition of underlying structures; and, if opportunity presents, to follow the trend of growth in serial radiographs over a period of years.

This brief review of the development of pretreatment analysis of malocclusion will serve as an introduction to the following critique of Angle's classification, Simon's system, and the more recent advances in this field.

Critique Of Present Methods of Denture Analysis

It is only by retaining the good in previous methods and sifting out error that a system can be built up which will attain to the high standard demanded by present day orthodontic service. Simply to regard everything in the past as of no value, is to sweep away the foundation upon which such a system can be erected.

Cuspal Relation

Angle made a real contribution to dental knowledge, in his observation on the relation of the "inclined planes of the teeth". No other single factor in denture relations exhibits such constancy in the human family irrespective of race, as does the cuspal interdigititation.
The form of the arches, and the orientation of the whole denture to cranial structures, may vary with the racial characteristics, but the cuspal relation follows the basic pattern which we have come to regard as the greatest single feature of a normal masticatory apparatus.

No system of denture analysis can be satisfactory unless the occlusal relationship of the teeth is taken into account. This must be the starting point of the analysis, irrespective of the additional procedures which may be adopted to confirm or modify the tentative decision.

First Permanent Molar Stability

Dr. Angle based his classification almost solely on the relation of the "inclined planes of the teeth when the jaws are closed", assuming, not without reason, that the upper first permanent molars were almost invariably in normal mesio-distal relation. The whole fabric of the classification stands or falls on this assumption.

It is a fact that the first permanent molars usually have unrestricted space for eruption, not requiring co-ordinated resorption of any preceding teeth; but all have, no doubt seen cases presenting impaction of the first permanent molars and second deciduous molars, caused either by a mesial placement of permanent teeth or failure in mesial growth of the maxillary arch. Two such cases are shown here. (Fig. 14)

Such instances could be multiplied but these will serve to illustrate a possibility which must be admitted.

Relation to Key Ridge

The relation of the upper first permanent molar to the key ridge has been advocated as a guide to its normality. No one can fairly doubt a functional relationship here. Irrespective of race the first permanent molar is never found to encroach on the canine fossa anterior to this buttress of bone. Atkinson has shown the dire results which can follow such a mesial movement of the molar tooth, resulting in a resorption of cortical bone and protruding of the buccal root apices. There seems little doubt that the general functional design of the jaws, provides for the close relation of the key ridge and first molar tooth.