Eighteen Years of Research At Illinois

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When the Department of Graduate Orthodontia was established at Illinois in the fall of 1929, a small, two-page announcement was printed for the benefit of applicants. In this announcement three objectives were set forth. They were (1) the training of scientific practitioners of orthodontia (2) the conducting of research and (3) the training of teachers. This report will concern itself with only one of these three efforts, viz, the research of the department.

One of the stipulations made when the department was under consideration was that the University provide it with a Broadbent-Bolton Roentgenographic Cephalometer and the necessary xray equipment to complete it. At this time there was only one such machine and that was the one in use at Western Reserve. Broadbent had yet to announce his invention formally to the profession but the author had been so fortunate as to meet him at the Angle School in 1926 and had been permitted to share in the developmental steps that preceded his announcement. When he was approached with the idea of building a second machine for Illinois he accepted the assignment enthusiastically and, although the task proved to be costly and time-consuming, installation was completed in May 1931. The university could not have made a wiser investment because this instrument has been responsible for most of our research efforts.

It should be realized that at the time we were in possession of very few facts about the field of orthodontia. Oppenheim had given the profession his outstanding contribution of 1910-11 and we were aware of the changes that took place around a moving tooth. But he had made certain assumptions relative to functional development and these assumptions were swallowed quite as readily as were his actual findings. Indeed, these assumptions were taught here for a number of years, and very enthusiastically, as members of the earlier classes will testify.

We were very cocky about our ability to move teeth in any direction in those days, our only concern being for the establishment of perfection of interdental relations. Our relapses were blamed on our own shortcomings in technique or on lack of cooperation by the patient. Likewise, we were very certain of our knowledge of the etiology of malocclusion. Class II was held to be due to mouth breathing at the time when the first permanent molars were erupting. This caused the patient to keep the teeth out of occlusion and since all first molars erupted cusp-to-cusp, or so we said, the mandibular pair failed to share in the forward growth of the upper jaw and thus became locked in a distal relation. Once this happened the case became Division I if the habit persisted or Division II if the child's pride caused him to attempt to cover his protruding teeth. It was all very simple and beautiful and logical, but why we ignored the fact that Division I did not become progressively worse with age, since the open mouth persisted, is a mystery. Class III was explained on the basis of sore tonsils which caused the patient to protrude the mandible in swallowing. In a similar way a cross-bite was always held to be due to a sleeping or leaning habit and all sorts of bizzare malocclusions were explained on the basis of premature loss or prolonged retention of deciduous teeth, upon mesial drift and ectopic eruption.

It should be noted that all of the etiological factors enumerated were acquired or environmental. Anyone who dared mention the word "heredity" was looked upon with suspicion. He was thought to be looking for an excuse for failure and was warned that he had better perfect his techniques and his case analysis. We spent just as much time on analysis as we do today although it was all based on plaster models and photographs and the excellence of our techniques were the result of far more hours of bench work.

Our original interest in the cephalometer unquestionably lay in our desire to find out what happened to the face as a result of orthodontic treatment. We wanted to know how fast the mandible caught up with the maxilla after correct occlusal relations were established and how much we widened the nose when we expanded the arch. We *knew* we moved teeth distally but how far could we move them and how fast?

Fortunatly we did not confine all of our attention to our clinic patients but took records of all unusual cases that came to our notice. I am not certain that this was due to any deep and compelling scientific curiosity but rather to an effort to justify the expenditure for the equipment, or a human desire to "show-off" a method unknown to our medical brethren. But curiosity ultimately became the dominant factor and all sorts of unusual conditions were x-rayed and filed away. It was during this early period that the work on the hypothyroid child was begun in conjunction with the Department of Pediatrics and also the intensive study of the hypopituitary patient in which we collaborated with the University of Chicago. Only the difficulty of transporting the equipment prevented our studying the hypopituitary dwarfs at the World's fair in 1933-34.

About this time it began to dawn on us that we should collect some controls and we cast about for a suitable population for this purpose. After trying a number of orphanages in the city, all of which raised their eyebrows at us, we made a contact with the Mooseheart City of Childhood. Dr. Reymert, director of research at that institution, was establishing his institute there and he lent a sympathetic ear to the proposal that a long range dental research program be started. He agreed to send a group of children to Chicago once a week. This group of seventy children was to have a complete mouth examination, intra-oral x-rays, profile and full-face photographs and cephalometric roentgenograms, plaster impressions, lactobacillus count and dental plaque analysis, and this was to be repeated semiannually. Naturally this involved other departments in the dental school and once a week the departments of therapeutics, x-ray, photography and orthodontia had their hands full.

We had known that the program would be an expensive one and could not be long continued without outside support but temporarily the costs of transportation and feeding were underwritten by the Loyal Order of Moose and the University assumed the cost of supplies and materials. This program was in force for a year and a half when application was made to the Rockefeller Foundation for a continuation grant. This was refused and the entire project had to be dropped.

In order to complete this story I should tell you that again through the good offices of Dr. Reymert we were able to examine this same group eight years later. The same records were repeated and these data, all now on file in the department, have proven of great value in some of our recent studies.

Before entering upon a recital of research projects, attention should be called to one case which, more than any other that comes to mind, demonstrates the value of taking records — even when one does not know at the time just how they may ultimately be used.

Dr. Moorehead, then Head of the Department of Oral Surgery, came into the orthodontia clinic one morning with a girl, fourteen years of age. She had an ankylosis of rather sudden onset and he planned to resect both condyles. The girl had a quite pronounced Class II malocclusion and he proposed that we place appliances and "jump her bite" in conjunction with the surgery. This we agreed to do and this work was undertaken by Dr. Myer. Of course, we took headplates on the spot. The procedure proved to be highly successful and the patient dropped from sight after treatment was completed.

Some three or four years later, while working on the problem of mouth-opening and the role of the external pterygoid in this movement I was regretting our inability to put this muscle out of function experimentally. It suddenly occurred to me that a resection of the condyle did just this and I remembered our patient, or rather Dr. Moorehead's patient. When we called her, wonder of wonders, she still lived at the same address and readily assented to having new records made. Upon viewing her lateral headplates, I lost all interest, temporarily at least, in mouth opening, because here was a mandible deformed over a period of four years into the "sled-runner" jaw of Angle or the Vogelgesicht of the European literature. We had the main lead to the growth of the mandible — the condylar process.

In the early years of the department it was routine procedure to award the Master of Science degree if the candidate had been accepted on the basis of the prerequisite educational credits and had carried more than the required eight units of graduate work. The thesis requirement was waived for all early classes because their calendar year of residence automatically insured the accumulation of eleven or twelve units as against the required eight. For this reason there was not much research done by the students although a few elected to carry out certain investigations which were subsequently published. One of the first of these was Steadman's study of the mathematical formula of the gradients of growth of the rat incisor done in Dr. Schour's department.[1] A formula had been announced some years before by Erdheim of Vienna and Erdheim himself acknowledged that Steadman's formula was the correct one when Schour met him in Vienna in 1936.

Another piece of work not done for credit was that of Kloehn in 1937 on "The Significance of Root Form as Determined by Occlusal Stress".[2] Kloehn analyzed the working areas of the teeth of the carnivore, the herbivore and the incisor of the rodent and sought to determine whether there was a ratio between such working area and the surface of the root that offered resistance. His findings were most interesting, to wit:

1. In animal dentures at least, each tooth seems to function individually.

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[1] The Growth Pattern and Daily Rhythm of the Incisor of the Rat. Anat. Rec. Vol. 63, pp. 325-332, Nov. 1935.

[2] Angle Orthodontist, Vol. 8, pp. 213-230, 1938.

2. In no case is the entire occlusal surface of even the individual tooth in function at any single instant.
3. The root form of any tooth reflects its occlusal stress.
4. There is evidence that a uniform ratio between root surface and functioning surface may exist and it appears that this ratio is similar regardless of the function and stroke, whether in rodent, carnivore or herbivore.
5. The approximate ratio between working area and root surface is 1 - 40 for the mandible and 1 - 50 for the maxilla.

These findings indicate that further investigation along these lines might prove very fruitful and I have always regretted that the work was not continued.

In 1937 we moved into the new building and the task of packing records and transferring them forced upon us the realization that we had accumulated a large amount of material. With an Angle Society meeting in prospect the staff decided to take stock and report its findings. We had then been in operation for six and one half years and our records were complete on a considerable number of cases.

A division was made on the basis of classification with Dr. Downs assigned to Class I, Doctors Myer and Goldstein to Class II and the author assigned to Class III. A common method of appraisal was worked out and this was followed for all cases. Every case upon which the records were complete was appraised and those exhibiting typical findings were worked up for presentation. Before reviewing the findings of this investigation I should like to call your attention to our then existing theories of the effects of orthodontic treatment.

Following Angle's pronouncements on normal occlusion and the classification of malocclusion which was based thereon, it had been taught that normal function would lead to or at least toward normal development. One had only to establish normal occlusion and hold it while vigorous function was promoted and the result would be the best form and balance for that face. We, therefore, expected to see some rather sweeping changes in the records of our cases — all of which had been considered clinically successful. We set ourselves an imposing array of objectives for the study but were content to settle for relatively few before we were finished. We found we had not taken records sufficiently often to answer a number of questions we had asked ourselves. But the findings we did announce were disquieting enough to satisfy us. Since the entire report is available in the literature and is known to most of you, I shall not take time to recite detailed findings. The general summary will serve the present purpose adequately.[1]

1. The orthodontist is able to move teeth and to do so without markedly disturbing their axial inclinations. Tipping is the predominating movement, however, unless great care is exercised to prevent it.
2. In all cases in which elastics were worn there was a disturbance in the angle formed by the occlusal plane and the Bolton plane. In Class II treatment the angle opens and in Class III it closes.

[1] Angle Orthodontist, Vol. 8, pp. 261-351, October 1938.

3. There is a tendency for the angle to return to its original size following treatment. This tendency diminishes as age advances.
4. In a number of cases of all classes a part of the result obtained is shown to be contributed by a change in the position of the mandible. This is occasionally a horizontal, anteroposterior shifting but more frequently it consists of a downward and backward rotation of the mandible.
5. Axial inclination of teeth, disturbed by orthodontic management, tends to correct itself following treatment.
6. Actual bone changes accompanying orthodontic management seem to be restricted to the alveolar process. The ability of this structure to adapt itself to changes in the position of the teeth is extremely great.
7. Changes subsequent to treatment are limited to shiftings in the occlusal plane and to changes in axial position of teeth in adult cases. In growing children there are, in addition, the typical changes that are expected in growth.
8. There seems to be a definite correlation between success in treatment and growth. The adult cases, although clinically successful so far as the maintenance of occlusal relations is concerned, are not so markedly improved esthetically.

This piece of work was presented before the Edward H. Angle Society in May, 1938 and I would not wish to leave the impression that it shocked the audience by its revelations; indeed, it confirmed the suspicions of quite a few who were growing skeptical of some of the previous teachings. It has been claimed that the resurgence of extraction resulted from it, although it did not appear until after Tweed had advocated the procedure. Be that as it may, it certainly added fuel to the flame.

In 1937 the Graduate School announced that no more Master's degrees would be granted with the waiver of thesis. This meant that all candidates who wished to take the degree would have to submit a thesis based on original investigation. We were immediately faced with the problem of deciding on fields of investigation to be explored.

The matter of classification had long intrigued us, and particularly that of the Class II case. Angle had stated, 1899, that Class II was characterized by a distal position of the mandibular teeth and by 1905 had only added the words 'jaw and dental arch.' Controversy arose over his insistence that the maxillary first permanent molar was a reliable basis for classification and in spite of the anthropometric researches of Hellman and Oppenheim, both of whom verified his contention, the entire matter became very confused. Much of this confusion, I am sure, stemmed from the common failure of men to take the trouble to read original sources and to content themselves with an acceptance of somebody else's opinion or statement of what the original author had said. As a result, the Class II mal-occlusion was held to be different things by different men. There were those who claimed that the mandible was normal in position and the maxilla forward to normal; others held that it was a matter of equal and opposite displacement of both; a few supported Angle's contentions but without any evidence to prove their conviction. Finally, there was a considerable group which apparently based their judgments on the total facial appearance and who claimed that the mandible was underdeveloped. Not infrequently one heard the terms "Class II" and "underdeveloped mandible" used interchangeably.

With the method of x-ray cephalometry at our disposal we decided to investigate this problem and the task of determining whether or not the mandible in Class II differed from that in Class I was assigned to Dr. J. William Adams.

CEPHALOMETRIC STUDIES ON THE FORM OF THE HUMAN MANDIBLE

J. W. Adams
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This investigation was initiated to determine whether variations in mandibular form were associated with specific malocclusions classified according to Angle. A random series of 140 cases were studied. The cephalometric roentgenograms were traced and linear and angular measurements of the mandible were recorded. The following angles were noted:

1. The gonial angle. This angle was studied in greatest detail.
2. The angle between the lower mandibular border and the occlusal border.
3. The angle between the lower mandibular border and the surface of the chin.
4. The angle between the lower mandibular border and the gnathial-incisal edge.

The findings failed to demonstrate any correlation between age and the gonial angle. In addition there were no significant differences shown in this angle in Class I (M = 125.7°; o— = 6.9°) and Class II (M = 126.6°; o— = 6.6°) cases.

The absolute dimensions of the mandible in Class II malocclusions did not differ essentially from those observed in Class I; this would seem to rule out mandibular underdevelopment as a factor in Class II malocclusion.

When Class III malocclusions were analyzed notable differences were recorded. These were as follows:

1. The gonial angle was greater (M = 132.1°; o— = 6.4°)
2. The angle at gnathion was always less.
3. The occlusal plane formed a more acute angle with the lower mandibular border.
4. The antero-posterior width of the ramus was significantly less than that of younger individuals in the other groups.

Dr. Adams' findings seemed ample testimony that the Class II mandible was so similar to that of Class I that underdevelopment could hardly be claimed to be its chief characteristic. It also indicated strongly that the relation of its parts, as for instance, body to ramus differed in no way from the normal. This left the possibility, however, that the teeth might be in posterior relation to the bone, under which condition the occlusion would be of a Class II nature. The task of determining what, if any, difference existed in this regard was assigned to Dr. Earl Elman.

STUDIES ON THE RELATION OF THE LOWER SIX-YEAR MOLAR TO THE MANDIBLE[1]

EARL S. ELMAN

This study was undertaken in order to gain new information on one specific aspect of the problem of Class II malocclusion, namely, the relationship of the mandibular six-year molar to the body of the mandible.

All measurements in the study were taken from lateral cephalometric films; one group consisted of a control series of 72 different individuals from the Mooseheart Home for Children, ranging in age from 3 to 10 years, with two-thirds of the group over 6 years of age. Nearly all had a Class I molar relationship and a few had Class II molar relationship and two or three showed Class III molar relationship. The second group was a series of 42 Class II cases selected at random from the clinical records in the Department of Orthodontia at the University of Illinois.

Two base lines were established for purposes of measurement: one tangent to the lower border of the mandible, and the other tangent to the posterior border of the ramus. A vertical measurement was taken by measuring the length of a perpendicular to the lower border from the distal contact point to the first permanent molar; an anteroposterior measurement was taken from the same point on the tooth to the posterior border of the ramus, measured parallel to the occlusal plane. Where right and left sides failed to superimpose on the film, a mean between the two shadows was used. A graphic representation of the relationship between the anteroposterior measurement (the distance from the lower six-year molar to the posterior border of the ramus) and the vertical measurement (the distance from the lower six-year molar to the lower border of the mandible) may be shown for the control group by means of a scattergram, with one dimension represented on the ''x'' axis and the other on the ''y'' axis. When these points are so scattered it becomes evident that most of them fall on or near a straight line. In similar fashion, the individuals in the Class II group may be represented by a similar scattergram, where once again a straight line relationship obtains.

Comparison of the two groups may be made from these scattergrams in order to discover essential differences. Upon inspection it is apparent that the angle formed by the straight line through the points in the control group is virtually identical with that same angle in the Class II. This may be confirmed by determining the angular relationship between the base line and the line through these single points, from which a mean angle for each of the groups may be calculated. The mean angle for the control group was found to be 34.51 degrees, while the mean angle for the Class II group was 34.30 degrees. Obviously this is not significant and it suggests that the lower six-year molar is situated identically in the two groups with respect to the posterior border of the ramus and the lower border of the body of the mandible. The mean vertical measurement for the control group was 21.56 mm., while that for the Class II group was 25.27 mm. The mean horizontal distance for the control group was 31.24 mm., while that for the Class II group was 36.90 mm. These differences reflect age differences between the two samples, and may be disposed of by calculating a ratio between horizontal and vertical values for each of the two groups. Such a ratio indicates that the vertical measurement is equivalent to approximately two-thirds of the horizontal measurement, not only when means alone are considered, but when ratios are calculated for each of the individuals within the study, irrespective of age. This relative constancy between the two relationships is further reflected by the fact that the standard deviation for the angles previously referred to for the control group was 0.94 degrees, and 1.22 degrees in the Class II group. These findings, therefore, clearly indicate that there is no essential difference in the manner in which the first permanent mandibular molar is situated on the body of the mandible in the two classes of malocclusion under study, insofar as the anteroposterior and vertical dimensions are concerned.

[1] *Angle Orthodontist* 10:24-32 (Jan.), 1940.

I think you will all agree that Dr. Elman's finding were striking, to put the matter very mildly. When one mentions standard deviations of .94 and 1.22, the narrowness of variation suggests physical and not biological studies. We considered the point proven that the relation of the teeth to the mandible was identical in Class I and Class II. Naturally, our thoughts now turned to the maxilla in an effort to discover what relations existed here. Would we find similar conditions of stability or would we find that the maxillary molars were forward as some claimed? This task was assigned to Dr. J. Philip Baldridge.

A STUDY OF THE RELATION OF THE MAXILLARY FIRST PERMANENT MOLARS TO THE FACE IN CLASS I AND CLASS II MALOCCLUSIONS[1]

JOHN PHILIP BALDRIDGE

This study was undertaken to determine the relation of the chin point and the upper first permanent molar to the face and cranium in Class I and Class II malocclusions. The material upon which this study was based was taken from cephalometric roentgenograms of the patients with malocclusions; 50 were Class I's; 36 were Class II, div. 1's, and 21 were Class II, div. 2's. Only the initial roentgenogram of each patient was used, to avoid including material wherein orthodontic treatment had been instituted.

The position of the maxillary first permanent molar and/or the point gnathion in relation to the face and cranium were measured by angles:

1. Angle N-S-*6*, nasion-sella turcica-maxillary first permanent molar.
2. Angle N-S-Gn, nasion-sella turcica-gnathion.

The angle N-S-*6* yielded an arithmetic mean for each of the three groups (Class I, Class II, div. 1, Class II, div. 2) which was, for all practical purposes, identical with that in the other two groups. The arithmetic mean for the angle N-S-Gn was essentially the same in Class I and Class II, div. 2, but in Class II, div. 1, the mean was about 2 degrees larger than in the other two groups.

These findings suggest that gnathion bears the same relative anteroposterior position to the cranium in Class I and Class II, div. 2, while in Class II, div. 1 that point indicates that gnathion is in a more posterior position to the cranium. The practical identity of the angle N-S-*6* in the three groups bears out Angle's contention that the upper first permanent molar assumes the same relation to the face and cranium in various classes of malocclusion. The validity of the use of the upper first permanent molar as a basis for classification is therefore supported by these findings. The findings also suggest that the mandible is in a posterior relation to the cranium in Class II, div. 1 malocclusion, but that it is situated normally with respect to face and cranium in Class II, div. 2, possibly with a longer base bone in Class II, div. 2 than in Class II, div. 1.

[1] *Angle Orthodontist* 11:100-109 (Apr.) 1941.

Again in this study the remarkable stability of the molar teeth was demonstrated. Although somewhat larger standard deviations were met with it should be noted that the means of the N-S-6 angle were identical and it should be remembered that a similar precision of measurement to that of the lower was not possible. The upper 6 could not be located in its relation to the bone that actually held it. But apparently the upper first permanent molar was not the unreliable will-of-the-wisp that it had been held to be.

On the other hand, with almost identical standard deviations the chin point was shown to be 2° posterior in Class II Div. 1 when compared to Class I and Class II Div. 2. If the mandible is no different in size or angular configuration as shown by Adams, and if the teeth bear the same relation to the ramus and body as shown by Elman, and if the chin point is posterior as shown by Baldridge it seemed evident that the bone, including the joint, must be posterior in Class II Div. 1 cases. This would place the fault in the cranal base, i.e., in the variability in the placement of the temporal bone.

But Baldridge's work had posed another question. He had separated the two divisions of Class II and had considered them independently. By so doing he had shown that although the molar relation was identical the chin point was not. Class II Div. 2 exhibited the same spatial position of this point as Class I. This indicated that the lower border of the mandible was longer in Class II Div. 2 than in Class I or Class II Div. 1. This claim had previously been made by Hellman but had apparently been ignored. It seemed wise for us to lay out a study of the total facial pattern and Dr. Earl Renfroe was assigned this task.

(Dr. Renfroe's paper is published in full and begins on the next page. This running account of research is resumed on p. 16).

A Study of the Facial Patterns Associated With Class I, Class II, Division 1, And Class II, Division 2 Malocclusions[1]

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Brodie and Broadbent in their longitudinal studies on the growth of the human head have shown that the pattern is established in early infancy and thereafter does not change. This pattern is most accurately represented by the angular relations existing between its various parts, and since angles are representative of proportion it is possible, through their employment, to eliminate differences that are due to absolute size and age. Using these facts as a basis a pattern of any head or the average pattern of any group of heads may be laid out from a single base if the angles are known.

The material for this study consisted of 95 lateral cephalometric roentgenograms of untreated malocclusions. These cases were divided according to Angle Classification as Class I, (43 cases) Class II division 1 (36), and Class II division 2 (16). Each roentgenogram was traced and the angular readings were made from the tracings.

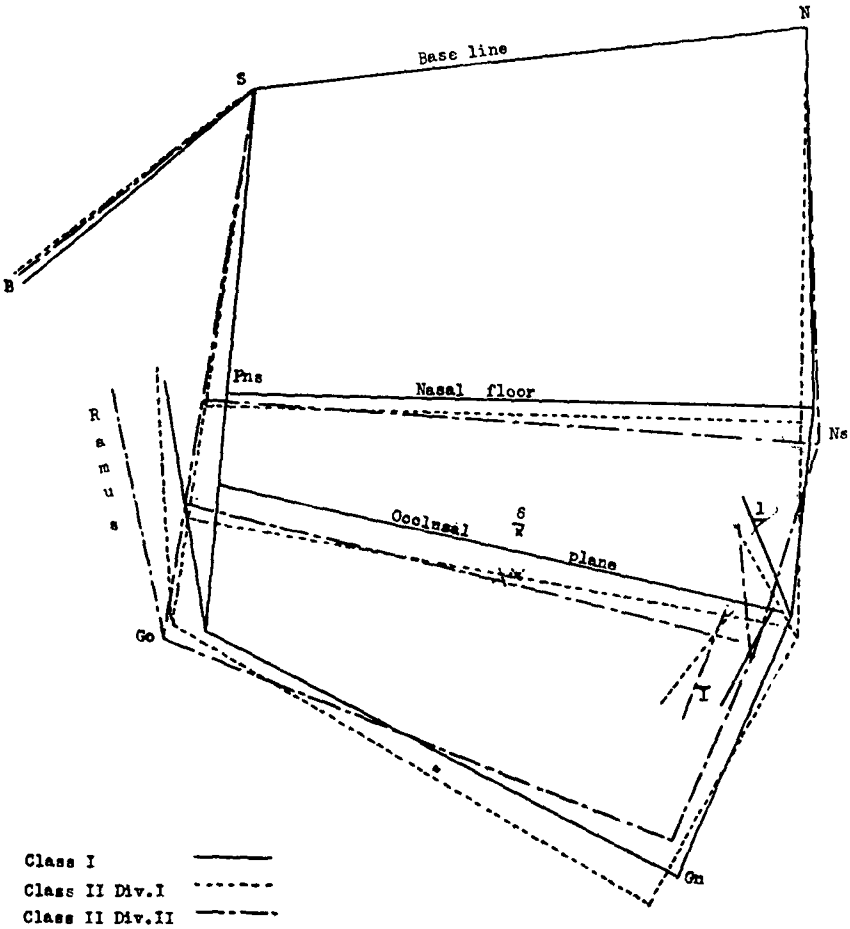
The landmarks used were N (nasion) the junction of the frontal and nasal bones; NS, the anterior nasal spine; I, the maxillary central incisor at the incisal tip; 1, the mandibular central incisor at the incisal tip; Gn (gnathion), located halfway between the most anterior and inferior points on the bony chin; Go (gonion) a point representing the angle of the mandible that is formed by lines which are tangent to the inferior and posterior borders of the mandible; 6 the maxillary first molar at a point indicating the junction of the mesial and distal buccal cusps; PNS the posterior nasal spine, and S, the center of sella turcica.

Angular measurements were made from S and N (the ends of the base line) to all facial points that were to be studied. These were tabulated and grouped for each class of malocclusion. Means were established for all angles in each group and a composite pattern was drawn for each group from an S-N line of arbitrary length. For example, in order to locate the anterior nasal spine in the pattern of a group, a mean of the angle S-N-NS was laid out on a straight line from N. Then the mean of the angle N-S-NS was similarly laid out from S and the point at which the two lines intersected located the position of NS the anterior nasal spine.

Nineteen angles on each tracing were constructed, read and tabulated according to class. A mean for each angle of each class was calculated by totalling the readings and dividing by the number of cases in each class. After the points were located in relation to the S-N line they were connected by straight lines to show the facial type of the class.

In addition to the above angles which are concerned with facial form, two planes were established: (1) the nasal floor, by connecting NS with PNS and (2) the occlusal plane, by a line connecting a point representing half the incisal overbite and half of the molar cusp height. The angular relations of these two planes to N-S were read.

[1] Submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Illinois, 1941.



The mandibular angle was recorded in two ways: first as in the disarticulated bone, with a tangent to the lower border taken as one leg, and second, with the Go-Gn line in the facial pattern as one leg.

The author's interest in the axial inclination of anterior teeth prompted the recording of the angle between a projection of the axis of the maxillary central and the S-N line. The axis of the lower central was projected inferiorly to the Go-Gn line and its angular relation to this line was read.

TABLE I

MEANS OF ANGLES

Angle	*Class I*	*Class II Div. 1*	*Class II Div. 2*
N-S-B	146.6	147.9	146.6
N-S-Gn	67.9	70.3	67.3
S-N-Gn	75.2	73.7	74.3
N-S-Go	101.7	104.7	105.1
S-N-Go	38.8	37.1	37.3
N-S-NS	36.2	37.9	38.4
N-S-NS	85.0	82.9	85.1
N-S-$\underline{6}$	65.5	69.1	68.0
S-N-$\underline{6}$	54.2	55.1	56.0
N-S-$\underline{1}$	50.9	51.8	55.7
S-N-$\underline{1}$	82.4	82.9	78.5
N-S-$\overline{1}$	50.9	53.4	53.8
S-N-$\overline{1}$	80.7	76.6	76.2
S-N-Axis $\underline{1}$	105.0	111.4	88.0
Go-Gn-Axis $\overline{1}$	95.3	96.6	90.3
N-S to Nasal Floor	8.0	8.0	10.0
N-S to Occlusal Plane	19.4	17.5	20.2
Ramus-Go-Gn	126.6	123.0	122.6
Mandibular Angle	128.1	126.2	126.5

Summary

A study of the composite patterns of Class I, Class II division 1 and Class II division 2 malocclusion reveals the following tendencies:

1. The maxilla, as indicated by the position of the anterior nasal spine is definitely farther forward in Class I and Class II division 2 than in Class II division 1. Due to its increased forward inclination, however, the tip of the maxillary central incisor in Class II division 1 is just as far forward as is that in Class I, while the tip of the same tooth in Class II division 2 is definitely retruded. The position of the maxillary first permanent molar is almost identical in both divisions of Class II and this position is slightly back of that in Class I.
2. The nasal floor is nearly parallel in all three groups although showing some tendency to tip downward in back in Class II division 1.
3. The occlusal planes in Class I and Class II division 2 tend to parallel each other while that in Class II division 1 is lower in back.
4. The chin point (Gn) is farthest forward in Class I and farthest back in Class II division 1. Class II division 2 is intermediate.
5. The point Go is almost identical in Class II division 1 and Class II division 2 cases and both are posterior to that in Class I.
6. The mandibular angle is almost identical in Class II division I and Class II division 2 and is smaller than that in Class I.
7. The greater mandibular angle in Class I permits the condyle to meet the cranium at approximately the same point as that in Class II division 1 in spite of the more forward position of the mandible in Class I.
8. A comparison of the Class II division 1 pattern with that of Class

II division 2 reveals the latter to be a more square type. Its gonial point is set relatively lower and its gnathion point higher than in Class II division 1. In other words, the posterior face height (S-Go) is relatively greater and the anterior face height (N-Gn) is relatively less. Class I tends to approximate Class II division 1 but the face is relatively shorter.

9. Although the mandibular angle is the same in Class II division 1 and division 2, the difference in the form of the face noted above, results in a throwing back of the ramus in Class II division 2, so that the condyle meets the cranium more posteriorly than in either of the other two types.
10. The lower border of the mandible is of the same length in Class I and Class II division 1. Class II division 2 is slightly longer.

Conclusions

The summary of findings in this study when taken together with those of Adams, Elman and Baldridge would seem to permit the following conclusions:

1. That Class II malocclusions of both division 1 and division 2 types are not characterized by any lack of development of the mandible.
2. That the maxillary first permanent molar, instead of being anterior to its normal position in Class II malocclusion, has a tendency to lie more posteriorly as previously pointed out by Hellman, Oppenheim and Baldridge.
3. That Class II is characterized by a posterior position of the mandible as claimed by Angle.
4. That the angle of the mandible is larger in Class I than in Class II cases of either division.
5. That while the dental arch is posterior in Class II division 2, the chin point is almost as far forward as in Class I. This arises through the fact that the Class II division 2 case is a more square type with a mandibular border that is more nearly horizontal.

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EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

ALLAN G. BRODIE

(Cont. from p. 11)

Upon completion of Dr. Renfroe's work we felt that we could make certain statements relative to the Class I and Class II types of malocclusion. The first of these was that Angle had been jusified in accepting the upper first permanent molar as a basis for classification. The second was that there was a more fundamental difference between the two divisions of Class II than had previously been thought. While both seemed to have in common the more posterior relation with the cranial base, the longer lower border of the mandible in Division 2 permitted the chin point to match the position of Class I. Prior to this time we had taught that the differences between the two divisions lay in the mouth breathing factor, the Div. 1 case being a mouth breather and the Div. 2 case being a nose breather.

You have probably noticed that no studies had been directed toward Class III thus far. The reason for this lay in the fact that we had not collected a sufficient sample of this class, in spite of the fact that all members of the early classes had treated at least one such case. Looking over our collection we found that we had accumulated at least the original records on forty four cases. Two students were put on this work, one to study the upper and lower first molars, and the second to analyze the facial pattern. Dr. Robert Schoenwetter wrote his thesis on the subject of "The Relation of the Upper and Lower First Permanent Molars to the Face in Class III Malocclusion."

Dr. William Stapf worked on the problem of: "A Roentgenographic Appraisal of the Facial Pattern in Class III Malocclusion."

The Relation of the Upper and Lower First Permanent Molars to the Face in Class III Malocclusion[1]

ROBERT F. SCHOENWETTER, D.D.S., M.S.

Oshkosh, Wisconsin

What is referred to as Class III Malocclusion (Angle) is thoroughly familiar to us through the distinctive conformation that it gives to the face. It has been known over the last 200-300 years under various names such as underhung jaw, inferior prognathism, or the Hapsburg jaw.

This deformity is invariably associated with a rather definite type of abnormal occlusion which is known to us as Class III Malocclusion; the Angle classification is based on the relationship of the teeth of one jaw to those of the other, with the upper first permanent molar considered as having a rather definite and specific relationship to the facial skeleton and cranium.

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[1] Based on a thesis submitted in partial fulfillment of the requirement for the degree of Master of Science, University of Illinois, 1940.

There has been controversy over the validity of accepting any tooth as a stable base from which to measure deviations and positions of other teeth. Various authors have advanced ideas indicating that Class II and Class III malocclusions might be one of several conditions, any one of which might exhibit the same tooth relationship.

The morphology of the condition has been confused with the possible etiologic factors that have been advanced and these latter have frequently influenced the opinions of the various authors.

The etiologic factors which have been suggested may be classified under 1. habits, 2. growth disturbances, 3. heredity, 4. endocrine disturbance.

Thus it may be seen that in Class III malocclusion some authors consider the mandible to be an over-developed bone, others consider it to be a warped bone, while another group supports the theory that the maxillary, through its underdevelopment, is to blame.

Recent study on the developmental patterns of the face and cranium indicate that a definite inherent growth pattern is present in the individual and in similar groups, and that in abnormal cases such as Class III malocclusions the normal pattern is disturbed in the early stages of differentiation.

Mandibular form in Class II malocclusion was found to be the same as that in Class I cases. The abnormality in Class II in most instances was the result of distal positioning of the entire mandible, and not the result of underdevelopment. However, the mandibular form in Class III malocclusions is definitely changed, indicating that the normal inherent growth pattern has been affected.

Further work on the stability of the maxillary and mandibular first permanent molars in Class I and Class II malocclusions show that these units of the denture are stable in relation to the face. This further establishes the concept that the Class I and Class II mandibles are similar, but that the spatial relationship is different.

This study is an application of the same method used in the above work to a study of the molar relationship to the upper face and the mandible in Class III malocclusions with a view to determine whether or not a like stability exists.

Material and Method

Data consists of measurements from tracings of twenty-six cephalometric radiographic headplates in the files of the Orthodontia Department of the University of Illinois.

Each case studied was clinically diagnosed as a Class III malocclusion. Only headplates taken before treatment were used in this study. Age ranged from four to twenty-nine years.

Complete tracings of these headplates were made and the following points, planes and angles were constructed.

Linear Measurements

N-S: Line connecting nasion to the center of sella turcica.

S-$\underline{6}$: Line connecting the center of sella turcica to the buccal groove of the maxillary first permanent molar.

OCC: Line representing the occlusal plane determined by connecting the mid-points of the over-bite in the incisor and molar regions.

Go-Gn: Line representing the lower border of the mandible.

Go-H: Line representing the posterior border of the mandible.

L-$\overline{6}$: Line perpendicular to the inferior border of the mandible drawn to the distal contact point of the mandibular first permanent molar.

J-$\overline{6}$: Line drawn parallel to the occlusal plane and connecting the distal contact point of the mandibular first permanent molar to the posterior border of the mandible.

Angular Measurements

N-S-$\underline{6}$: Nasion-sella turcica-buccal groove of the maxillary first permanent molar.

J-6-L: Angles formed by the intersection of the lines J-6 and L-6.

The following planes and angles were measured and recorded:

1. S-$\underline{6}$
2. J-$\overline{6}$
3. L-6
4. N-S-$\overline{6}$
5. J-$\overline{6}$-L

The angles N-S 6 and J-6-L were measured with a transparent protractor.

All linear measurements were made with correctional scales.[3] These correct for the error of enlargement which is present in any radiographic work in which the object to be radiographed is not in a plane with the film.

Findings

From the data gathered in this cross-sectional study, graphs were plotted on millimeter paper to illustrate the position of the maxillary and mandibular first permanent molars.

A graph was plotted using the distance J-$\overline{6}$ as the abscissa and L-$\overline{6}$ as the ordinate. Each point which represented an individual case was connected to the zero point of the graph and the angle this line made to the base was measured.

The mean angle was determined to be 30.3° with a standard deviation of 1.46°. We must remember that this is a mathematical and not an anatomical angle.

A frequency curve was then constructed and it was found that 20 of the 26 cases fell within the limits of 29-33°.

Upon comparing these results with the work done on Class I and Class II malocclusions it was found that this mathematical angle in Class III is less; this is interpreted as indicating that the relative height of the mandibular first permanent molar in comparison to its distance from the posterior border of the ramus is proportionally less in Class III malocclusions: The ratio of the distance J-$\overline{6}$ to L-$\overline{6}$ in Class I and Class II cases is as 3 to 2 while in Class III cases the ratio is as 3 to 1.68.

Measurements taken from cephalometric radiographic head-plates of a group of normal children and adult Class III patients reveal that the height at the symphysis (Gnathion to the incisal edge of the mandibular teeth) is proportionally greater in Class III malocclusions than in the other two classes.

This information, together with the difference in ratios, indicates that the angle formed by the occlusal plane to the inferior border of the body of the mandible is greater in Class III than in Class I cases. This was verified by direct measurement of this angle in the two types of cases. In Class I cases the average was found to be 6°, while in the Class III series it was 16°.

This indicates that the occlusal plane, in relation to the inferior border of the body of the mandible, is higher at the symphysis and lower in the first permanent molar region in Class III than in Class I cases.

In the study of the upper first permanent molar in its relation to the face, the same method was used as that employed in the study of the upper first permanent molar in Class I and Class II cases.

The angle formed by the nasion-sella plane to the sella-6 plane was measured. The arithmetic means and the standard deviations for the angle N-S-6 in Class I, Class II, and Class III malocclusions are as follows:

MALOCCLUSIONS	ANGLE N-S-6	
Class I	Mean	S. D.
Class II Div. 1	67.95°	2.87
Class II Div. 2	68.47°	3.15
Class III	67.86°	2.96
	66.71°	3.72

These data indicate that in Class III malocclusion the maxillary first permanent molar is further forward in relation to the cranial base plane and to sella turcica than in Class I and Class II cases.

CONCLUSIONS

Data obtained from this investigation suggests that:

1. The maxillary first permanent molar in Class III malocclussions differs in position from the same molar in Class I and Clas II cases in that it is further forward in relation to the cranial base planes.

2. The position assumed by the upper first permanent molar in Class III malocclusion appears to be a definite one for this class.

3. The mandibular first permanent molar in Class III malocclusion differs in its position in relation to the mandible from the same molar in Class I and Class II cases.

4. The position assumed by the mandibular first permanent molar in Class III cases appears to be definite for this class. The range of deviation in the cases studied was greater than that exhibited in Class I and Class II.

5. The height of the mandible in the molar region in Class III malocclusion is less than in Class I and Class II cases.

6. The height of the symphysis, (gnathion to the incisal edge of the mandibular incisors) is greater in Class III than in Class I and Class II cases.

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.

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46 Washington Blvd.

A Cephalometric Roentgenographic Appraisal of the Facial Pattern In Class III Malocclusions[1]

William C. Stapf, D.D.S., M.S.

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The variety found in Class III malocclusion is extremely wide, considering etiology, morphology, chronology, and location of condition. This study is concerned only with the morphology of Class III malocclusion.

Literature on the subject is extensive, but reference is made here only to those dealing with the morphological aspect. The morphologic types recognized in the literature are: the contracted and reduced palate, the over-developed mandible, the lengthened rami, the lengthened mandibular body, the forward position of the temporo-mandibular articulation, the phylogenetic pattern, and the pathologic forms.

In general, all these writers described a contracted and reduced palate form of Class III. Brash[1] contended the abnormally over-developed mandible was accompanied by an over-development of the mandibular arch and soft tissue parts derived from it. Schwarz[2] felt the Class III condition was due to the lengthening of the rami of the mandible. Angle cited the occasional case of the mandible appearing to be over-developed in the body and another condition caused by forward positioning of the condyle in the temporo-mandibular articulation.

These writers mentioned the possibility of certain Class III malformations being of genetic origin. Class III malocclusions have been found in the stone age man and in other mammals, the anthropoid apes, dogs, etc. Fisk[3] called incipient Class III growth disharmonies; the typical varieties being inherent overgrowth of the mandible, the atypical varieties by diminished maxillary growth of genetic origin.

The pathological form of Class III malocclusion accompanied by endocrine disturbances was noted by many of the observers. Keith and Campion[4] described acromegaly as overgrowth of the supporting bone, particularly the chin and supporting element. Some explained the prominence of the chin and supporting mandibular elements in acromegalics as due to the influence of the enlarged tongue and mouth musculature.

In some acromegalics they found only the mandible responded to overgrowth, with the maxilla not affected. The angular region of the mandible appeared under-developed and the vertical over-development of the upper jaw alveolar elements led to a pressing downward of the mandible, thus opening the angle of the mandible.

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1 Based on a thesis submitted in partial fulfillment of the requirement for the degree of Master of Science, University of Illinois.

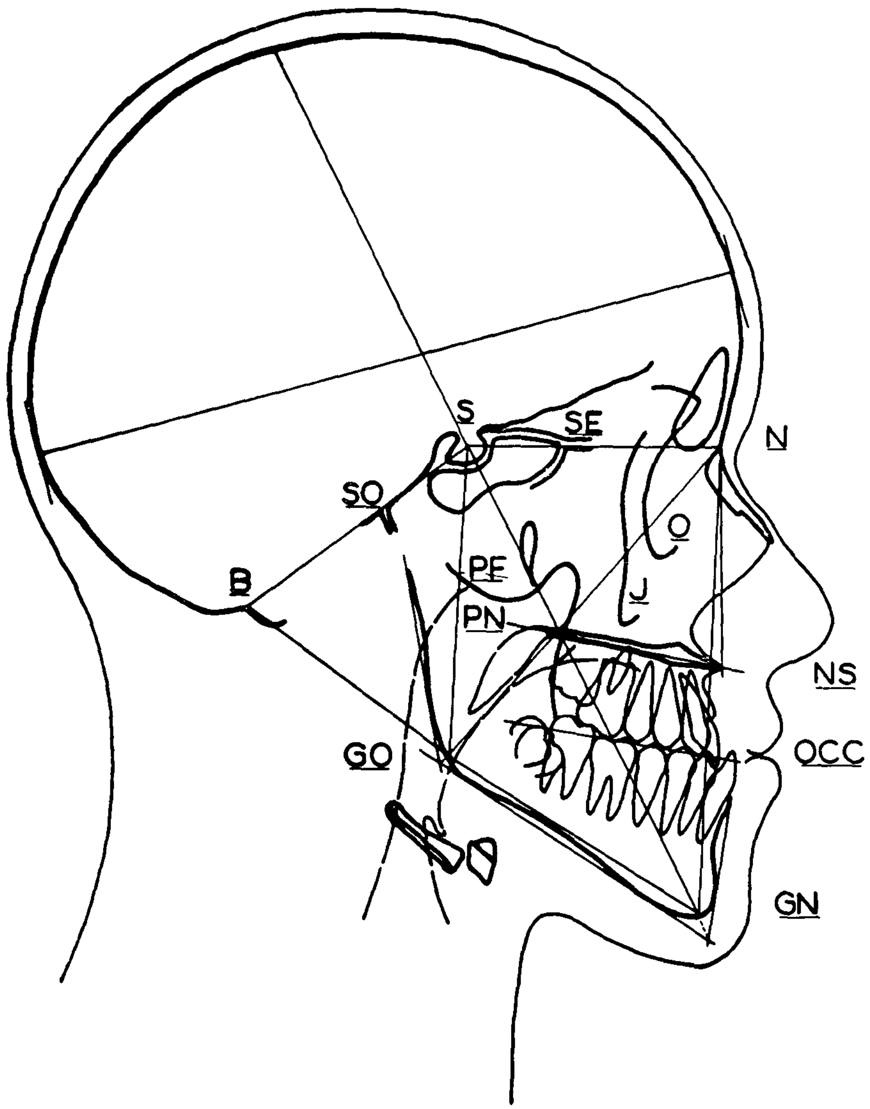

FIG. 1. Reproduction of a typical tracing from a cephalometric roentgenogram of a patient with a Class III malocclusion, indicating the points selected and the planes constructed for use in this study.

Method and Material

The material for this study consists of cephalometric roentgenograms of a group of thirty-seven individuals clinically diagnosed as Class III malocclusions. Selection was made without regard to sex, severity of deformity, or age. All roentgenograms were made before orthodontic treatment was initiated.

The method of assessing the head plates consisted of the complete tracing of the frontal and lateral films and the laying out of certain points, planes and angles.

The points were: Bolton, sella turcica, nasion, gnathion, gonion, orbitale, anterior nasal spine, the spheno-ethmoidal junction, the spheno-occipital junction, and the pterygo-maxillary fissure. The planes and angles were established from these points.

Linear measurements were taken by means of correctional scales, and the numerous angles were measured with a protractor.

To obtain a preliminary morphological picture of Class III malocclusion from these cases a mean pattern was constructed from the linear measurements and angles of the face; so that a mean facial pattern was constructed. The points used in this pattern were Bolton, sella turcica, nasion, gonion, and gnathion. The planes were the occlusal and nasal.

Findings

Class III patterns were compared to the normal facial pattern (established by Brodie[5] on twenty-one individuals eight years of age). Difference in age of the normal and Class III groups was discounted since it was shown previously by Brodie[5] that the angular pattern is unchanged after three months of life in the normal.

It was found that Class III facial patterns exceeded the normal in height. The similarities between Class III and normal patterns were: parallel lower borders of the mandibles, approximately parallel nasal floors, the constancy of relation of the point Go and the constancy of relation of the point Gn.

The differences between the normal pattern and that of Class III were found in the angle formed by the symphysis and the lower border of the mandible and in the angle at which the occlusal plane is placed in the pattern.

The nasal increment was found to be the same percentage height of the total face height in Class III as the normal eight year old group—43%; while the mandibular portion of the lower face height increment in Class III was considerably higher than in the normal, with less contributed to lower face height by the maxilla.

The cases showing the extremes of the angles S-N-Gn were superposed on the S-N plane at the point S. The two facial patterns were shown to be hafted to the cranium in a different manner. One of them is in an orthognathic position, while the other is in a retrognathic position. The hafting appears to be independent of facial type. The facial types were similar while the patterns of the cases at the inside extreme of angle N-S-Gn show a difference in facial type.

The cases at the extreme of angle N-S-Go revealed that each extreme was due to more than a craniofacial relationship. In this superposition the inclinations of the nasal floor and the occlusal plane are quite different.

When these extremes of angle N-S-Go are superposed at angle N-S-Go, this angle is found to be identical in both cases although there is a combination of differences within the patterns.

Discussion and Conclusions

From the literature of Class III malocclusion we can conclude that there are two theories concerning this deformity. Some authors feel it is an expression of a continuation of growth beyond normal limits, while others felt that the deformity represents an alteration in pattern. This study supports the continuation of growth beyond the normal by the regularity of points of Go and Gn, the parallelism of the lower borders of the mandibles, the almost parallel nasal floors, and the constant nasal height between the Class III and the normal pattern.

All Class III malocclusions have a distinguishing facial pattern, the major characteristic of which is the elongation of the face; they exceed the normal in height, thus the elongated effect.

Typing of Class III facial patterns appears to be independent of sex or of age in most instances.

Cranio-facial hafting bears no relationship to typing as far as could be determined in this study.

Cranio-facial hafting tends to add to or determine the severity of Class III deformities.

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EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

Allan G. Brodie

(Cont. from p. 16)

As may be seen from the work of Schoenwetter and of Stapf, the Class II pattern departs significantly from those of Class I and Class II. We feel that although Class III may possess one common etiological factor or one common morphological characteristic we do not yet know what it is. One cannot work with this malocclusion without feeling that it may be a number of different things because although the facial pattern seems quite typical from outward appearances, the x-ray reveals great variations in its parts. The mandible is not always deficient in height in the molar area nor is its angle always obtuse. In some the mandible is very heavy and quite normal in form. Investigations on this deformity have been hampered by lack of material. We hope that in the not distant future we shall have gathered enough cases to constitute a sample that will be satisfactory from a statistical standpoint.

In 1940 my own investigations on the Growth Pattern of the Human Head from the Third Month to the Eighth Year of Life,* were completed. During the six years that went into this work our concepts were gradually changing because of the evidence that kept piling up as the work progressed. This evidence had influenced us in our selection of thesis subjects before the work was completed, and the final conclusions reached and published were only in the nature of confirmation of concepts that had been developing for some time. Once we had formulated our conclusions, however, they became the basis from which new researches could be projected;

There were certain implications in this study that immediately opened research possibilities:

1. The pattern changes little if any during growth. It had previously been taught that the face swung out from under the brain case with the point of rotation at nasion. This error was due to the method that had been employed, i.e., the use of porion as a point from which measurements were made. This point goes downward and backward during growth and hence gave added values to longest dimensions, viz, the teeth and the chin point.

2. The value of angular over linear measurements was demonstrated. An angle represents a proportion between two dimensions, regardless of the length of its legs. This made possible the elimination of age in the comparison of individuals. Morphology was divorced from size.

3. The great quantitiative contribution made to facial growth by the mandibular condyle was pointed out.

4. The degree of individual variation of the various parts of the face was shown, but the constancy of proportion of those parts in any given individual was stressed.

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*Am. Jour. Anat., Vol. 68, No. 2, pp. 209-262, Mar. 1941.

5. Mandibular position was shown to be stable regardless of the presence or absence of teeth.

6. The stability of the pterygomaxillary fissure was pointed out.

7. The Y axis or axis of growth was defined.

At the same time we were employing cephalometric roentgenography for investigations we had been following growth by the use of another method, viz, vital staining. Brash's work, based on that of Hunter, had intrigued us at an early date and a series of circumstances led us to try something of a similar nature. The headplates were revealing quantitative aspects of growth but we wanted also to know where the growth was taking place.

Schour was working on the incremental pattern of the rat incisor and was employing sodium fluoride as his indicator. Although lines were easily demonstrable in both the dentine and enamel it was quite evident that they represented temporarily disturbed metabolism of these tissues. Thus there was always the possibility that artefacts might be present. In addition to this, the lines did not show up well in tissues of less homogeneity, such as bone.

Just at this time we were told that there was a pair of monkeys in the Department of Animal Husbandry at Urbana and that we could have them for the asking. Further than this, the female had just given birth to a baby so we were assured of a young animal. We promptly brought the animals to Chicago and began to hunt for madder. We finally located some of it, in the desired form of a fine powder, in our own College of Pharmacy. The monkeys, however, would have none of it in any form. This started the hunt for a substitute and Alizarine Red 'S' was the result. The testing of this material and the determination of dosage was done by Dr. Schour and Dr. Murray Hoffman and now injecions were given to every thing we could lay our hands on. I need not review the striking researches of Schour on the incremental pattern, the growth gradients and the neonatal ring that flowed from the application of the method. The material was found to be completely non-toxic and was finally given to one hydrocephalic infant, the disposal of which had been turned over to the hospital. This infant had a life expectancy of only a few months and lived for nearly a year and a half, receiving periodic injections. From this one child the incremental pattern of the growth of the deciduous teeth was worked out by Schour and his co-workers.

A number of monkeys were made available to us by the University of Chicago where a large scale investigation on poliomyelitis was then in progress. These were given periodic injections. The bodies were turned over to us upon sacrifice and the complete skeletons were cleaned and stored. It was from the heads of these animals that Massler and I studied the sites of growth and since this work has never been published in anything but abstract form, one may mention a few of the findings.

Until this time Brash's work had been taken as the explanation of head growth. He had maintained:

1. That the entire bone growth process was one of surface addition and resorption. This was consistent with all findings and beliefs of other investigators.

2. That the brain case enlarged by external deposition and internal resorption and that this was the responsibility of the bones themselves, and not of the sutures. He stated, "And I am led to the conclusion that the growth units are the bones themselves and not the sutures that unite them."

3. That the principle site of growth in height of the face was the alveolar process. As bone was piled on in this area the nose, orbits and sinuses developed by absorption of their floors. In short, there was deposition on the under surfaces and resorption of the superior surfaces of all horizontal partitions such as the floor of the orbit, the palate and the sinus.

The study of the monkey specimens failed to substantiate these contentions. We found stained bone on the superior surfaces of the floor of the orbit and nose and further than this, on the internal surface of the internal table of the skull-cap. What was equally striking was the deposition of the dye in suture lines in animals where no dye could be found on other surfaces. These apparent contradictions had to be explained and now the value of our x-ray findings became apparent.

Brash had called attention to the growth at the fronto-nasal suture and claimed that this and the maxillo-premaxillary suture were responsible for the growth of the pig's snout. We found a similar active growth at the fronto-nasal suture in the monkey but since the monkey's face is so to speak, vertical instead of horizontal as is the pig's, this growth expresses itself in height. Once we had grasped this fact we felt we had the explanation of the appearance of dyed bone on the upper side of the palate, on the floor of the nose and orbit. It can readily be seen that a growth which occurred on the maxillary side of the frontal process of the maxilla would result in a pushing down of the entire bone. Hence the orbits and the nasal cavity would have to increase in vertical dimension by the same amount as the total upper face. This would naturally maintain infantile proportions. Only by deposition of bone on the floors of these cavities could they be kept from growing too large. We found equally intense staining at the tuberosity and on the maxillary side of the maxillozygomatic suture. All of these sutural junctions lie in what amounts to a common plane and this plane is at right angles to the axis of growth which had been forced upon our attention by the radiographic studies. Mandibular growth had been thoroughly demonstrated by Hunter and Brash to be a matter of backward growth at the posterior border and our radiographic studies had drawn attention to the upward vector at the condyle. Putting this all together we had a new concept, viz, that the face develops downward and forward by growing, that is, by bone deposition, in an upward and backward direction against relatively fixed bases. This at once eliminated the idea that the teeth had to migrate forward through the maxilla in order to erupt. They had only to await the development of new bone at the tuberosity in order to erupt vertically.

Toward the end of this period of investigation there appeared a skeptical student. This particular man could not accept the method of vital staining as an indicator of growth. Unknown to us, he decided to check things for himself and accordingly bought himself some rabbits and went to work. He was Dr. Philip Levine and his thesis was written on the subject:

CERTAIN ASPECTS OF THE GROWTH PATTERN OF THE RABBIT'S SKULL AS REVEALED BY ALIZARINE AND METALLIC IMPLANTS

Philip Levine
Newark, N. J.

Sutural activity plays a major role in cranio-facial growth. The purpose of this investigation was to elucidate the mechanism.

The rabbit was the experimental animal used. Animals whose age ranged from 55 days to several months beyond adulthood were selected. The fronto-nasal and coronal sutures were exposed and amalgram inserts were made on opposing sides of the sutures. The distances between the points were then recorded. In three animals the sutural area was excised. All received periodic injections of alizarine Red "S", a dye which stains, in vivo, the sites of bone opposition. The animals were then sacrificed at varying post operative periods; the insert distances were measured, and the sites of alizarination were noted.

Surface apposition of bone was demonstrated strikingly when it was seen that the amalgam points in most instances were covered by a stratum of bone. The generalized staining of the skull in the younger animal further attested to the degree of surface activity.

Measurement of the inter-insert distance indicated a differential of growth between cranium and face. This is especially evidenced in long snouted animals such as the rabbit. Thus the area about the fronto-nasal suture grew four to five times more rapidly than that in the coronal region. The relative and almost absolute inactivity in the coronal area suggested early stabilization of the brain and brain case. The growth rate in the regions studied decelerated with approaching adulthood and then stabilized.

In those animals where the sutural area was extirpated, the adjacent bones continued to drift apart at the control rate. It was thought that this phenomenon might be accounted for by activity of the transverse palatal, premaxillary, malomaxillary or malotemporal sutures or of other sites lying in a related plane.

The suture is thus shown to be a site of growth activity, as well as a mediator of adjustment between adjacent bones.

As you have seen, this study convinced Levine that alizarination was an acceptable method but it also revealed to all of us a rather disconcerting fact. We could not trust surface examination for the deposition of the dye if fresh bone was so transparent that an amalgam plug, covered by several layers of this tissue, appeared to be on the surface. Henceforth we would have to section all bones at right angles to the surface to be studied. This is, of course, not difficult in the case of a compact bone such as the mandible but the delicate bones of the middle face are a different matter. This requires an embedding technique that will permit sectioning without fracture. Decalcification cannot be employed. This problem was given to Dr. Alton Moore.

A METHOD OF STUDYING THE CRANIO-FACIAL GROWTH SITES IN THE MACAQUE MONKEY AS THESE ARE EXHIBITED BY VITAL STAINING WITH ALIZARINE RED "S"[1]

Alton W. Moore
Seattle, Wash.

Introduction

This paper presents the results of an attempt to find a means of securing sagittal serial sections of a Macaque monkey skull that had been vitally stained with alizarine Red "S". All of the available and known histologic methods that would permit such sectioning require decalcification of the specimen and thus loss of the alizarine Red "S", as it is closely linked to the calcium of the bone.

Many studies of the cranio-facial growth sites have preceded this one and each has added to our knowledge of this subject. The methods and materials

[1] *Jour. Dent. Res.* 25:157 (June), 1946.

used have varied with the investigator, but by compiling their results we have now a fairly clear picture of these growth sites. Brash used a vital staining technic to study the cranio-facial growth sites in the pig, and grossly sectioned the skulls without an embedding medium in order to make his observations. It was felt that it might prove fruitful to repeat Brash's work, using the monkey and refining the technic, so that the results might be more applicable to the knowledge of growth in man.

Material and Methods

The Macaque monkey was selected as the animal of choice because the findings may more readily be transposed to our knowledge of human growth. The dental age of the monkey was comparable to a six-year-old human.

A method was sought for the embedding of these skulls in a hard substance that would permit the making of sections with the maintenance of accurate anatomical relationships.

The most satisfactory material found for the purpose was unpolymerized methyl methacrylate monomer. The inhibitor was removed from the monomer and an accelerator was added by methods previously reported by other authors.

The technic found to be most satisfactory for embedding skulls in methyl methacrylate was the partial prepolymerization of the methyl methacrylate in a water bath at 85°C, into two different consistencies; one, a thin solution having the consistency of glycerine, and two, a thick solution having the consistency of very heavy molasses. The thin solution will keep under refrigeration indefinitely while the thick solution must be used immediately after preparation.

The skull was prepared for embedding by cutting it into two halves along the midsagittal plane. Only half of the skull was embedded at a time. The cut surface of the skull was placed face down in a glass vessel and centered in relationship to the surrounding walls of the vessel. It was completely covered with the thin, partially prepolymerized monomer and subjected to vacuum for five to ten minutes and then allowed to stand at room temperature for twenty-four hours with a loose fitting cover. The specimen was then covered to an excess of one inch with thick, partially prepolymerized monomer which displaced the thin monomer and the vessel was left at room temperature for forty-eight hours or until the thick monomer was completely hardened. The thin monomer was still fluid and was decanted off at this time. In another twenty-four hours the surface was completely hardened. The final stage consisted of annealing the block in an oven at 50°C, so as to prevent checking or crazing.

This technic differs from those previously described only in the manner of embedding.

The next step was to find a means of sectioning the block of methyl methacrylate containing the specimen. The use of a band saw and circular saw was discarded because of the inability to obtain perfectly parallel cuts and the destruction of part of the specimen, by the saw blade. The method finally selected was sectioning by surface grinding and photographing each successive surface so that a record of each cut could be saved.

The outer surface of the prepared block was cut parallel to the midsagittal plane of the skull and mounted with methyl methacrylate on the face plate of a screw-cutting lathe. The specimen was mounted on a face plate to insure its return to the same position for further cuts, after it had been removed for polishing. A carbide tipped tool was found that would cut enamel, bone, and embedding media with equal ease. A special camera mounting was made to fit onto the bed of the lathe so that serial cuts could be photographically recorded with the same degree of magnification.

The lathe was set for automatic cross feed so that as smooth a cut as possible would be made. It was found that as little as .02 of an inch could be removed by each cut but not more than .04 of an inch. After each cut the block was polished with decreasing grits of sandpaper and then removed from the lathe for the final polish with a buff wheel upon which pumice and then Bendick polish had been applied. A photograph was taken after the block had been replaced on the lathe.

Findings

Schour and Massler have pointed out that two developmental periods can be recognized in the Macaque; "(1) an early period of 'generalized' growth in which apposition occurs upon all bony surfaces (periosteal, endosteal, epiphyseal and sutural) and (2) a later and more prolonged period of "localized" growth where bone deposition is confined to certain definite sites and chronologic periods. In the first period, developmental changes in form and proportions are due only to differences in the rate of apposition (growth gradients): in the second period, these changes are more conspicuous and are the result of the localization of the sites of growth and their interaction.''

The specimen used in this experiment was entering the second developmental period, i.e., predominantly showing sites of localized growth. The specimen was entirely pink before embedding, however, the localized or more active growth sites were stained more deeply. After embedding the specimen, the generalized pink coloration had been lost and it appeared as if only the active growth sites retained their stain.

Upon gross examination of the specimen the following sites of active growth were evident in the bones comprising the cranio-facial complex;

Maxilla
- Tuberosity
- Alveolar process
- Anterior surface of the body at the maxillary-zygomatic suture
- Tip of the frontal process
- Maxillary-palatine suture
- Superior surface of palatine process

Premaxilla
- Entire bone

Zygomatic
- Slight apposition of entire lateral surface
- Zygomatic-frontal suture
- Zygomatic-maxillary suture
- Zygomatic-sphenoid suture
- Zygomatic-temporal suture

Frontal
- Supraorbital ridge
- Frontal-parietal suture
- Frontal-sphenoid suture
- Frontal-zygomatic suture
- Roof of orbit
- Frontal sinus area
- Nasal-frontal suture
- Parietal
- Parietal-occipital suture
- Parietal-temporal suture

Occipital
- Condyle
- Occipital-temporal suture
- Basal part of Occipital-sphenoid junction

Temporal
- Lateral surface of zygomatic arch
- Temporal-occipital suture
- Temporal-sphenoid suture
- Temporal-zygomatic suture
- Margin of external auditory canal on anterior inferior edge
- Entire petrous portion

Sphenoid
- Anterior margin of lateral pterygoid process
- Sphenoid-temporal suture
- Sphenoid-parietal suture
- Sphenoid-frontal suture
- Wide margin of stain at parietal-temporal-sphenoid suture junction
- Portion of great wing that forms posterior wall of orbit
- Entire body
- Medial pterygoid plate
- Pterygoid fossa except lateral wall
- Entire infratemporal portion of great wing

Palatine
- Maxillary-palatine suture
- Lateral margin of pyramidal process
- Perpendicular plate at junction with medial pterygoid plate
- Superior surface of horizontal process
- Orbital process of palatine

Nasal
- Entire bone

This specimen is in the process of being cut at the present time so any further observations will have to be made upon the completion of this work.

You have probably realized by this time that this is not a strict chronological recital. The effort has been rather to give the sequence of work on particular problems and Dr. Moore is following today a line of research that was one of the first undertaken. Many of these different avenues were being followed simultaneously by different students. The next presentation is a case in point.

For a number of years there had been developing a skepticism of the statement that appeared in all anatomy texts to the effect that the suprahyoid muscles were the chief actors in mouth opening. Prentiss, Lord and Gromme had set up mechanical models which proved quite conclusively that the location and action of the external pterygoid made it possible for this muscle to perform the function. Shortly after this, in doing some reading for a course in muscle physiology, I happened across an article that had apparently been overlooked by these workers and was not even included in the exhaustive bibliography of Hildebrand. It had been written by a man named Chaim Chissin and appeared in the Archiv für Anatomie und Entwickelungsgeschicte in 1906. The title, translated into English was, "On the Opening Movements of the Mandible and the Part Played therein by the External Pterygoid."* This classical piece of work, done thirty years earlier had anticipated practically all later findings.

*Uber die Offnungsbewegung des Unterkiefers und die Beteiligung der äussern Ptergoidmuskeln be derselben. Archiv fur Anatomie und Entwickelungsgeshichte, 1906.

In 1937, I was assigned the Temporomandibular Joint* in a symposium on the subject of Occlusion. This necessitated a complete review and synthesis of the subject and as usual suggested problems for further study. The most obvious plan of attack was a comparison of normal and abnormal cases and Dr. John R. Thompson selected this work for his master's research. His thesis was entitled:

CEPHALOMETRIC INVESTIGATION OF THE OPENING MOVEMENTS OF THE MANDIBLE

JOHN R. THOMPSON
Chicago, Ill.

The controversy as to whether the suprahyoid muscles or the external pterygoids are the responsible agents in depressing the mandible, has long existed. A review of the literature reveals that most anatomical textbooks maintain that the suprahyoid muscles, because of their position of mechanical advantage, supply the motive power. This investigation consists of a study of the opening movement in normal individuals and in a number in which the influence of the external pterygoid muscles have been impaired or entirely eliminated (bilateral fracture of condyles, paralysis, bilateral and unilateral ankylosis and resections). In the normal opening the hyoid bone maintains a level well above that of the symphysis of the mandible and the suprahyoid muscles are not in a position of mechanical advantage to depress the mandible.

[1] *Jour. Am. Dent. Assn.* 28:750-61 (May), 1941.

In the abnormal cases where the external pterygoid cannot function, the hyoid bone is pulled downward below the level of symphysis so that the suprahyoids are now in a position of mechanical advantage. The depression, however, is a pure hinge movement and it is limited in extent.

I do not remember exactly the circumstances that led up to the investigation of the resting position of the mandible. Various studies had revealed bits of information about this matter but there had been no occasion to bring them all together. Viewed in retrospect I believe that the wave of "bite-raising" that swept the country about 10-12 years ago as a result of Costen's work** probably furnished the incentive. This procedure seemed contradictory to all our concepts but we suddenly realized that these concepts had never been exactly stated much less proven.

Reconstructing the development of our "hunches" took us back to the earliest days of the department when several of our staff and students and particularly Dr. Chester F. Wright, had worked with Dr. Frederick B. Moorehead on the reduction of jaw fractures. You are all familiar with this work but I doubt if many of you can comprehend how revolutionary Dr. Moorehead's ideas seemed when he first advanced them. In cases of maxillary fractures, where the middle face was broken and displaced this man had the temerity to suggest that the mandible, a floating bone, was the best source of anchorage and the occlusion of the teeth the best guide for correct reduction. All others were placing cumbersome head-caps and running wires through the cheeks for the purpose of securing stability between upper jaw and brain case. In cases where the mandible likewise was broken, sometimes in several places, it was Dr. Moorehead's practice to bring the fragments into correct relation with each other after which he would use it for anchorage in the reduction of the maxillary fracture. He had great faith in the occlusion of the teeth as guides and he liked orthodontic mechanisms because of the precision that was available in their adjustments.

After watching numbers of very complicated cases beautifully managed in this manner we began to sense the fact that the musculature which controlled the mandible was a very stable though complex system and that the reduction of jaw fractures was a matter of controlling this system through the fatiguing of those muscles that were maintaining the displacement of fragments. But, it must be confessed, we did not see the whole picture. We missed completely the free-way space and worse than this, we overlooked the fact that the whole matter had anything to offer in fields other than that of Oral Surgery. We even resented to a degree the fact that the Department of Oral Surgery occasionally called upon us for help in the handling of the more complicated cases. Two of our graduates, however, Dr. Wright and Dr. Kloehn, became very much intrigued by the problem and both men have devoted significant portions of their practices to this work. Both have published excellent papers on the subject* and Dr. Wright gave clinics on the method at the Ninth International Dental Congress in Vienna in 1936.

*Ill. Dent. Jour., Vol. 8, pp. 2-12, Jan. 1939.

**Glossodynia: Reflex Irritation from Mandibular Joint as the Principle Etiologic Factor. Arch. Otolaryng., 22:554-564, Nov. 1935.

My own thinking about the stability of mandibular position was greatly influenced by the finding that the jaws were wide apart at birth. It had previously been asserted that the gum pads were in apposition at this time and that the eruption of the teeth and the growth of the alveolar processes wedged the jaws apart. One of the angles measured in the growth studies was that formed by a tangent to the lower border of the mandible to the cranial plane S-N. This angle was found to be stable, indicating that the mandible did not change its relation to the face and cranium. Further than this, it was shown that the vertical proportions of the face present at birth did not change during growth, whether teeth were present or not. Nasal height was shown to contribute 43 per cent of total face height on the average, and the standard deviation of this measure was quite low. It was tested not only on large groups of patient records but on 600 skulls of widely diverse origins at the Chicago Museum of Natural History.**

By this time Dr. Thompson's work on the opening movements of the mandible was finished, and we began finally to wonder how the position of this bone could be altered by artificial means as was being advocated by the "bite-raisers."

Men doing this work were basing their procedures on the prevailing idea that the face lost vertical height when the teeth were lost or markedly worn. It was held that under these circumstances the chin approached the nose and the head of the condyle rode up into the glenoid fossa. The obvious cure was to restore the vertical dimension by raising the bite.

Dr. Thompson and I decided to make a direct attack on this problem, that is, to determine exactly what happened when a patient's bite was restored. For this we obtained the cooperation of the Examining Room and the Denture Department. All patients for whom dentures were to be constructed were sent first to the Department of Orthodontia and head x-rays were taken with the mandible in its rest position. If teeth were to be extracted they were sent back for this work and then immediately re-x-rayed to determine whether any change occurred.

Not much immediate denture service was being given so it was possible to recall these patients during the healing period for further x-ray checks and some of them were checked as many as five or six times before dentures were placed. Some ninety-odd consecutive cases were handled in this manner and in practically none of them did we find any alteration in mandibular position.

As soon as the dentures were placed the patient was x-rayed again and it was at this stage that the interesting findings began to develop. There were some in which the mandible was undisturbed and a free-way space of varying amounts was present. There were others in which the rest-position coincided with that where the teeth were in occlusion. Finally there were those in which the bite had actually been raised and the mandible was at a position lower than that assumed when at rest. Some of the dentures were complete, others partial, with occlusal rests on the abutments.

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*Wright, C. F., Angle Orth. Vol. 7, No. 2, pp. 67-80, Apr. 1937.
Kloehn, S. J., Angle Orth., Vol. 10, No. 2, pp. 94-100, Apr. 1940.

**Herzberg, F. and R. Holic. An anthropologic study of face height. Am. Jour. Orth. & Oral Surg., 29:90-99 (Feb.) 1942.

As time went on these patients were recalled and it was found that those in whom mandibular position had been altered were the ones that had had most trouble. They complained of jaw fatigue, ear and temple discomfort and those wearing partials presented depressed and frequently loose, abutments. Those who were wearing complete dentures and who persisted, gradually became comfortable but the x-rays revealed that without exception they had returned to their original resting positions at the expense of alveolar bone absorption. Those cases in which the dentures had merely eliminated the free-way space showed a restoration of this space. This fact we have never satisfactorily explained.

When this investigation was completed and written up it was submitted for the Chicago Prize Essay Contest but we had to be content with second place. Dr. Thompson, however, continued to work on the problem and now it began to expand into a concept that had ramifications in all fields of dental science. The rest position became the point of departure for diagnosis not only in denture and other restorative work but in orthodontia, periodontia, oral surgery and in the diagnosis of asymmetries and joint conditions. Two years later this widely expanded work took the prize.* I shall not refer further to it here because it will be given by Dr. Thompson later in this program. I cannot pass it, however, without stating that I consider it one of the most far-reaching investigations done in the department and one of the best examples of the practical results that can result from pure research.

This brings us up to the war years which witnessed the departure of most of our younger men and the depletion of our classes. There were times when we were down to two graduate students as in 1941-42, when Wylie and Carlson were our sole residents. Both of these men wrote theses based on original research.

Over the years there had been a number of theories advanced relative to the eruption of teeth. Most of these had been based on histological methods. Considering only the movement of the tooth it had been postulated that Hertwig's epithelial sheath was a stable point of reference for the eruption of each tooth. This was denied by Gottlieb who referred his measurements to ankylosed teeth and who, on the basis of his observations stated that the sheath moved with the tooth and hence could not be used. No study had ever been made employing points or planes of reference that were remote from the teeth. This was what Carlson elected to do. His thesis, which won the first Prize Essay Contest of the American Association of Orthodontists, was entitled:

STUDIES ON THE RATE AND AMOUNT OF ERUPTION OF CERTAIN HUMAN TEETH[1]

HARRY CARLSON
Sacramento, Calif.

The eruption of human teeth has interested investigators since early time and our knowledge of this process has been advanced in direct proportion to developments of methods for its study. Until cephalometric roentgenology was developed to a stage of scientific accuracy, however, it was not possible to study the complete process of eruption of teeth in the same individual or animal over a period of time. This study represents such an effort. It is restricted to a consideration of the rate, amount, and direction of the eruption of certain teeth, viz., the mandibular central incisor, canine, first and second pre-molars, and first molar.

[1] *Am. Jour. Orth. & Oral Surg.* 30:575-88 (Nov.) 1944.

*J. A. D. A., 33: 151-180, (Feb.) 1946.

Methods that have been employed in the rate, amount, and direction of eruption may be considered under the following headings:

1. Clinical
2. Histologic
3. Vital Staining
4. Roentgenologic

Clinical Method: Clinical observation is the oldest method, and the order of eruption of teeth through the gum was rather accurately laid out by investigators at an early date. More recently, there has been a great deal of work done on large samples of different populations. These have greater scientific value. Hellman observed and evaluated eruptions in 2,250 persons, and Kuttler observed 15,240 children and 782 adults. These findings showed quite definitely that the order and speed of eruption might be altered in malocclusion, sex, nationality, and economic status. All of these studies, however, deal only with the eruption of teeth from the time they pierce the gum.

Histologic Method: Although a great deal of work has been carried on by histologic methods, most of the studies have been of a qualitative nature. Thus they sought to determine the process through which teeth came to erupt.

Gottlieb, using ankylosed teeth as fixed points for measurement, studied the rate and amount of eruption. He concluded that Hertwig's epithelial sheath could not be a fixed point because permanent teeth continued to erupt long after they came into functional opposition to their antagonists. Weinmann pointed out that the horizontally placed bony trabeculae under the tooth germ varies at different periods of eruption. There seems to be first a period of slow eruption which is followed by a more rapid eruption. This in turn is succeeded by a second period of slow eruption as occlusion is attained.

Vital Staining: Hoffman and Schour measured the rate of eruption of rat molars by injection of Alizarin Red S at definite intervals. A red line formed at the crest of the alveolar process gave them the height of that process at the time of injection. Using this as a fixed point, they measured the distance from this point to the cemento-enamel junction. They concluded that "the rate of eruption of rat molars was greatest prior to the establishment of functional occlusion, and decreased with age"; also, that the initial appearance of the tooth in the mouth, at about the 19th day, would not markedly retard the rate at which the tooth was erupting; however, when the tooth came into occlusion an abrupt retardation became apparent."

Roentgenologic Method: Broadbent demonstrated very vividly the course of eruption of most of the teeth by superpositioning of tracings of successive stages of eruption of the same individual. Broadbent pointed out: First, the growing tooth may remain stationary while its forming root grows from the incisal or occlusal surface into the bone. Second, the tooth may migrate through the bone with little addition to its root length. Third, the root length addition and the migration of the tooth may occur at any time.

Material and Method

The material used in this study consisted of 5 series of lateral and frontal x-rays. Each series was of a single child, taken at six-month intervals over a period of ten years. The ages of the children overlapped so that the study covers the range of 3 months to 17 years of life. All five children had normal occlusion of the teeth.

All measurements were made from the tracings. Using a tangent to the inferior border of the mandible as a base line, corrected measurements were made to the lowest point of the root end, to the highest point of the crown, and to the occlusal plane directly over the tooth. Corrections for foreshortening due to tilting of the tooth were made from the frontal film. Correctional scales, developed by Adams, have been used to determine the error of enlargement.

It is a known fact that deposition of bone on the inferior border of the mandible is negligible even before the eruption of the permanent first molar. Therefore, we have a stationary base from which to make measurements.

Findings

1. Without exception, the teeth studied showed a constant increase in the distance between the tip of the crown and the lower border of the mandible, regardless of age.

2. During the period of crown formation of some teeth, notably the lower canine, there was a constant decrease in the distance between the lower border of the mandible and the open or forming end of the crown. In others, the open end maintained approximately the same distance between these two points.

3. Coincident with the beginning of root formation the distance between root end and mandibular border invariably decreased. Since the crown tip continued to move occlusally, this could be interpreted only as an actual downward growth of root into the subjacent bone. The amount of this downward growth was found to be 2 to 4 mm.

4. Following the downward growth of the root there was a period of rapid eruption of the teeth during which all points on the teeth were seen to increase their distances from the mandibular border. Such distances did not increase equally, however. The crown tip showed a greater movement than the root end, indicating that eruption was proceeding more rapidly than was root formation.

5. In most of the teeth the period of rapid eruption continued until the tooth came into occlusion, when there was a sudden slowing down. From this time on the tooth erupted only as rapidly as the occlusal plane arose.

6. Coincident with the attainment of occlusion there was seen a second period during which the root end decreased its distance from the mandibular border. This marked the completion of root formation.

7. Once the root was completed, the entire tooth again moved upward at the same rate as that of the occlusal plane.

8. The rate of eruption was different in different teeth, and the same tooth showed variations between individuals. The latter, however, were not as marked as the former.

9. The greatest rate of eruption noted for any one tooth was a lower second premolar which erupted 8 mm. in six months. The greatest rate of eruption for any one-year period was that of a lower central which erupted 12 mm. The greatest eruption for any two-year period was that of the lower canine which erupted 13 mm.

10. The increase in rate of eruption takes place long before clinical emergence of the crown.

11. Clinical emergence apparently does not decrease or increase the rate of eruption.

12. Rapid eruption does not start until the crown of the tooth is fully formed.

Summary and Conclusions

Scrutiny of the data reveals that during the period of crown formation there is very little movement of the tooth in an occlusal direction. With few exceptions the increase in the size of the crowns seems to be expressed in an occlusal direction. That is to say, there is no sinking down of the crypt as has been inferred by some authors. The early stages of root formation, however, which follow immediately upon completion of the crown, do show a downward growth of the root of from 2 to 4 mm. This is not accompanied by any acceleration in the occlusal movement of the germ.

After the small amount of root noted above has been formed, the entire tooth begins its most rapid phase of eruption. This is characterized by rapid acceleration in the occlusal movement of the tooth and a slightly less rapid rise of the forming end. The difference between the two rates is due to the growth of the tooth itself. The rapid phase of eruption continues in most teeth until occlusion is reached, when slowing down occurs. From now on the root is completed by forcing its way down into the bone of the jaw. Upon completion of root formation the entire tooth continues to rise with the occlusal plane. This last point substantiates Gottlieb's contention that there is a perpetual eruption of human teeth.

EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

ALLAN G. BRODIE

(Cont. from p. 33)

The question of the influence of heredity as an etiological factor in malocclusion has been a much debated question for hundreds of years. Most of the evidence consisted of examples of similarity between members of a family and was necessarily of a purely subjective nature. The latest effort of this sort had been that of Hughes and Moore at Michigan who had compared a large number of characteristics of a group composed of mixed stocks. It occured to us that since the pattern of the individual did not change so far as angular relations were concerned, it would be possible to make an objective comparison between individuals on the basis of angular measurements. Fortunately, we had in our files the records of a number of pairs of twins as well as families with three or more children. Dr. Wylie elected this difficult problem as the field of his research.

A QUANTITATIVE METHOD FOR THE COMPARISON OF CRANIO-FACIAL PATTERNS IN DIFFERENT INDIVIDUALS. ITS APPLICATION TO A STUDY OF PARENTS AND OFFSPRING

WENDELL L. WYLIE
San Francisco, Calif.

Cephalometric headfilms in centric occlusion were obtained upon members of 13 different families, all but 2 of which included twins of the same sex. No attempt was made to distinguish monozygotic from dizygotic. On each of the sixty-five lateral headfilms so obtained, angles were formed by connecting the following facial points: sella, nasion, anterior nasal spine, posterior nasal spine, gnathion and gonion. Also included, bringing the list of angles up to 12, were the gonial angle and the angles formed by prolonging the line nasion-sella to intersect the extension of the hard palate, the occlusal plane, and the lower border of the mandible, respectively. There were two purposes behind the recording of this data: first, to study the behavior of the facial measurements in a group of the population and within the members of one family, discovering not only whatever resemblances occur within the members of one family, but the extent of variation to be found in a non-related group. Secondly, it was hoped that a quantitative method of measuring facial resemblance between two or more individuals might be established. On the first score it was discovered that no easy generalizations might be made about resemblances of facial pattern among related individuals and that marked similarity of facial skeleton could be observed only in twins wherein outward facial resemblance was striking. Furthermore, less resemblance in facial skeleton was found in several pairs of markedly similar twins than was to be expected from outward appearance. The study also showed unmistakably that there was a definite independence in behavior of the various facial features studied; that is, one cannot predict with any degree of accuracy the behavior of one facial characteristic as expressed in an angular value, knowing some other angular value or group of values. The attainment of the second objective was fairly clear-cut and involved the use of the standard deviation as a unit of measurement of variation with respect to each of the angles under consideration. When tracings of two different individuals were compared quantitatively, identity with respect to a given value led to a score of 0 in the rating system, while a difference of one-half of one standard deviation for that particular angular value or less led to a score of 1, while a difference between two individuals of one standard deviation or less led to a score of 2, and so on. In this fashion, a rating of dissimilarity was established for the comparison of the two individuals, with a relatively high score indicative of dissimilarity in the facial skeleton. The lowest score, indicating close similarity was 4 in a pair of twins who would undoubtedly be judged monozygotic by the usual criteria; the highest score was 77, obtained by the comparison of tracings of a man and his wife.

[1] *Am. J. Anat.*, 74 (39-60), Jan. 1944.

The dearth of students during the war was not an unmixed evil because it permitted us to do one piece of work that we had made repeated efforts to start. This was a longitudinal study of head growth from birth to the third month of life. Scammon and Caulkins[1] at Minnesota and Saunders[2] at California had worked on series of fetuses and had demonstrated that body proportions did not change during this period. Broadbent's series started at three months and had been studied from this period to the eighth year. A blind spot existed therefore between these two spans. Repeated efforts had been made to get permission to study the newborn in various hospitals but one thing or another was always raised as an objective. Finally, however, we obtained the sympathetic cooperation of our own Department of Obstetrics in the Research and Educational Hospital and at a most opportune moment. One of our students at the time was Manuel Ortiz of Guatemala, a man who had an excellent background for the work and who was easily persuaded to accept a Graduate Fellowship for the purpose of carrying out the investigation. He spent the next two years at it with the support of the Graduate School.

Dr. Falls, Head of the Department of Obstetrics, placed a room immediately adjacent to the delivery rooms, at our disposal, furnished us with nursing assistance and provided Dr. Ortiz with facilities to make it possible for him to live in this room so that he woud be available for call at all times. Dr. Spence of the class of '37, who had done his thesis under Schour on the growth of the head of the albino rat,[3] had designed a small-animal cephalometer which we modified somewhat and to which we added a table and tube stand. Dr. Ortiz paper will be published in the Anatomical Record.

This brings us up to the post-war period, and the work of the past two or three classes is an accurate mirror of the problems that have been interesting us these past few years. Some of these are follow-up studies made possible by accumulation of material over the years. For instance, Engel as a senior dental student and later as a graduate student had become interested in the hypothyroid child and had written his Master's thesis on the subject of:

A ROENTGENOGRAPHIC CEPHALOMETRIC APPRAISAL OF UNTREATED AND TREATED HYPOTHYROIDISM

MILTON B. ENGEL, I. P. BRONSTEIN, ALLAN G. BRODIE, and PHILLIP WESOKE
American J. Dis. Child 61: 1193, 1941

A cephalometric roentgenographic study of children with thyroid deficiency was initiated with a view to determining the mode and the sites of dysplastic growth. Investigation of the efficacy of thyroid therapy was a subsidiary objective.

It was shown that cranio-facial, dental, and carpal ossification patterns of development of untreated children with hypothyroidism lagged behind those of treated children. The deficiency in cranial development lay in the occipital, the parietal, and to much lesser extent, the frontal areas. The cranial base was shortened and the spheno-occipital synchondrosis and the vault sutures were abnormally wide. The face showed a generalized retardation of growth as a result of the slowed velocity of growth of its components, that is the mandible, the maxilla, and the nasal bones. The teeth were delayed in their eruption.

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1 The University of Minnesota Press, 1929.

2 Unpublished Data.

3 Angle Orthodontist, Vol. 10, No. 3, pp. 127-139, July 1940.

but they were not malformed. Differentiation and ossification of carpal centers was disturbed and retarded, and the roentgenograms showed persistence of infantile characters.

When the cranio-facial, dental, and carpal patterns of development of untreated children with hypothyroidism were compared to those of normal subjects of the same age they were shown to be retarded. The differences were merely an accentuation of those noted between treated and untreated cretins.

It is noteworthy that hypothyroid children who have been treated regularly since early childhood closely approach normal levels of cranio-facial development. Their patterns of dental development and progress in ossification are normal.

Thyroid deficienccy, then, affects cranio-facial growth by retarding its velocity rather than by modifying its pattern.

By the end of the war sufficient material of a longitudinal nature had been collected to permit a study of cases that had been treated and examined over significant periods of time and this task was undertaken by James Gold.

A Serial Roentgenographic Cephalometric Appraisal of Treated Hypothyroid Children

(AN ABSTRACT)

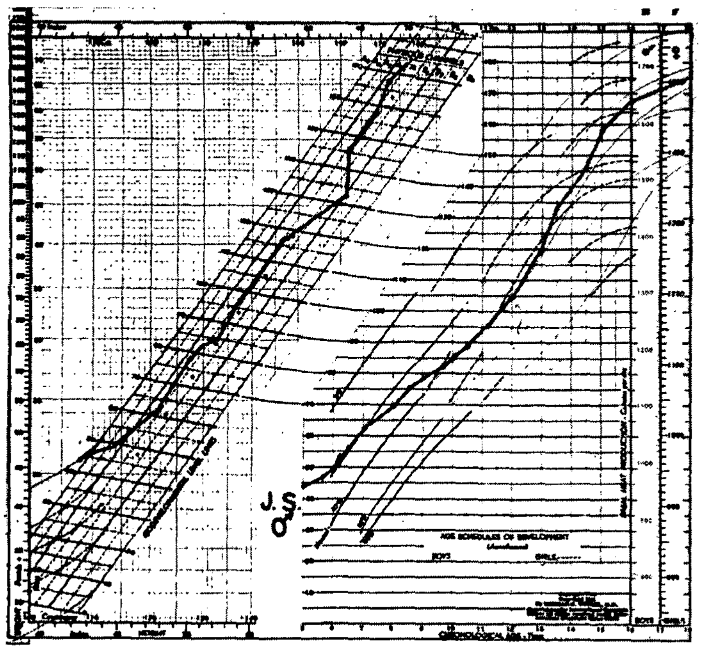
JAMES S. GOLD, D.D.S., M.S.
MILTON B. ENGEL, D.D.S., M.S.
AND
I. P. BRONSTEIN, M.D.
Chicago, Ill.

An initial cephalometric roentgenographic appraisal of hypothyroid children was published in 1941[1]. In that report untreated and treated thyroid deficient children of the same age were compared and a static picture of the effects of thyroid deficiency was obtained.

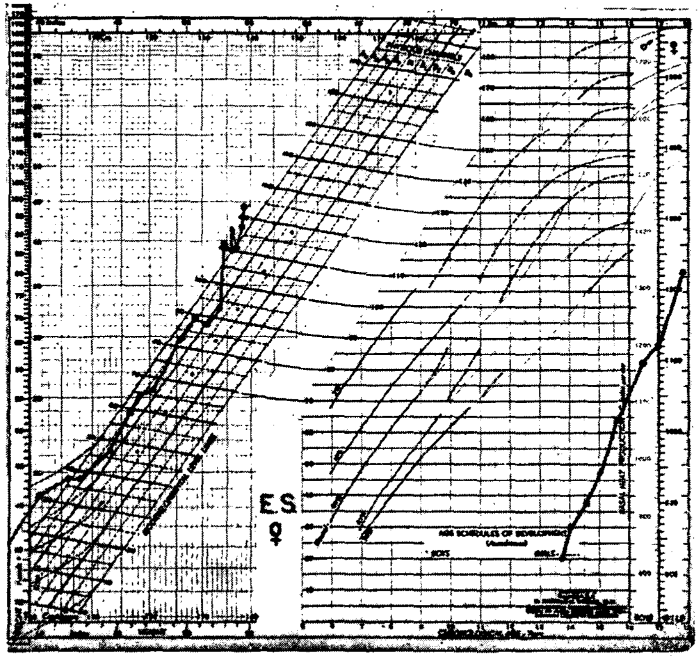
The present report was based upon a twelve year study of the craniofacial development in thyroid deficient individuals. The purpose of this study was to reveal the developmental response of these subjects to thyroid therapy, with emphasis upon the craniofacial development.

Eight selected cases of hypothyroidism were studied, considering the craniofacial, carpal, and general development. Cephalometric roentgenograms were taken at irregular intervals. The lateral roentgenograms of each individual were traced and serial progress was noted. Some significant craniofacial landmarks were measured and the angles tabulated. These dimensions and angles were compared with control data obtained from a study of Brodie's normal development series[2]. Carpal ossification was determined from the available hospital records and this was tabulated as given in the roentgenographic reports. The general development was assessed by means of the Wetzel Grid for Evaluating Physical Fitness.

Two cases are illustrated in this abstract to indicate the trend of the observations. Case J. S. represents the response of a child who has had early and adequate treatment. Case E. S. demonstrates the response of a child whose treatment was started late and whose development is retarded. (Figures 2, 3, 4, 5 and Grids I and II)



Grid I



Grid II

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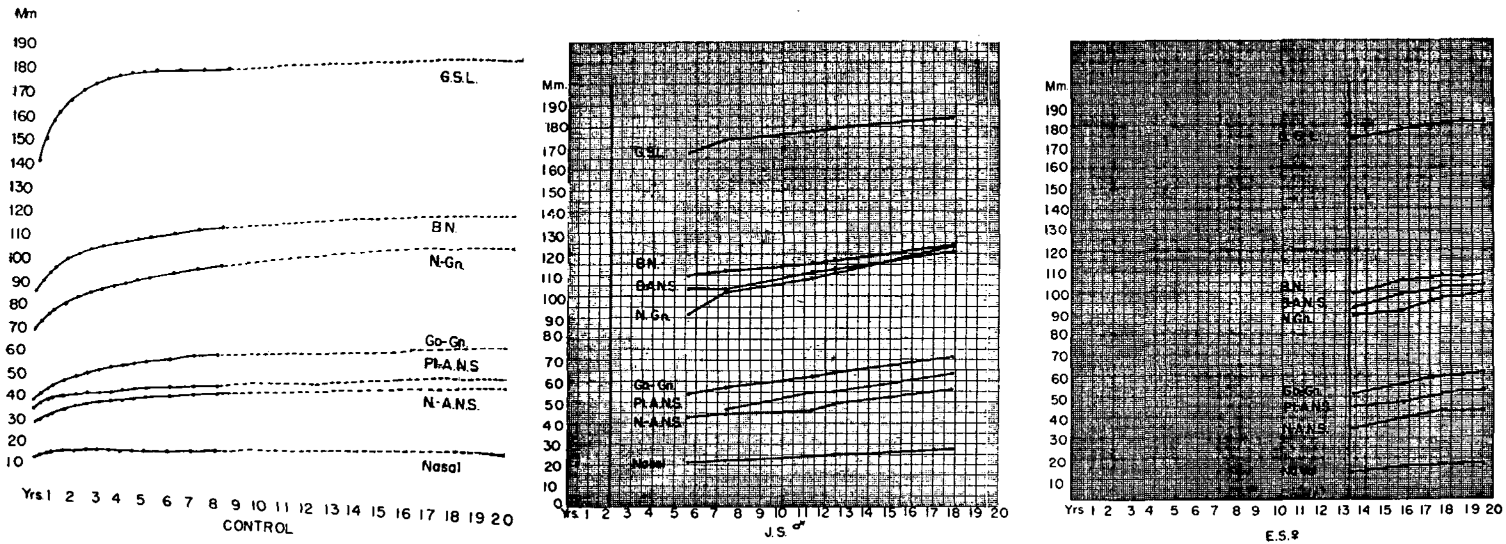

Fig. 2

Fig. 2. The control graph was developed from data obtained from Brodie (2). The broken line extension was extrapolated. The graphs of cases J. S. and E. S. show the relationship between early and late therapy. The vertical line represents the initiation of adequate therapy.

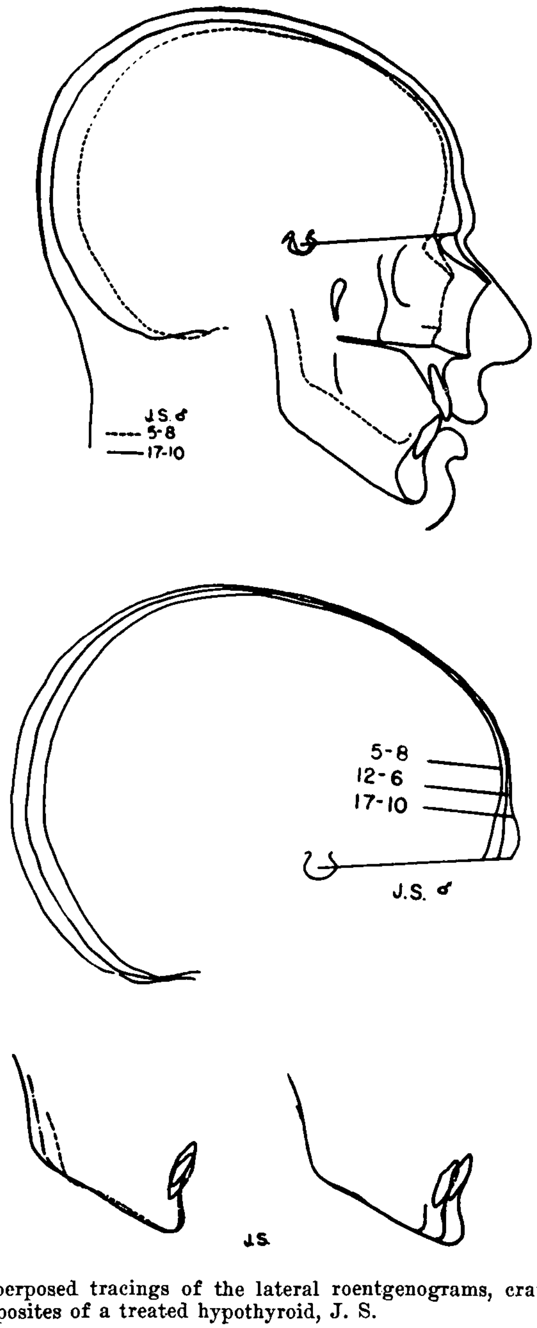

FIG. 3. Superposed tracings of the lateral roentgenograms, cranial composite and mandibular composites of a treated hypothyroid, J. S.

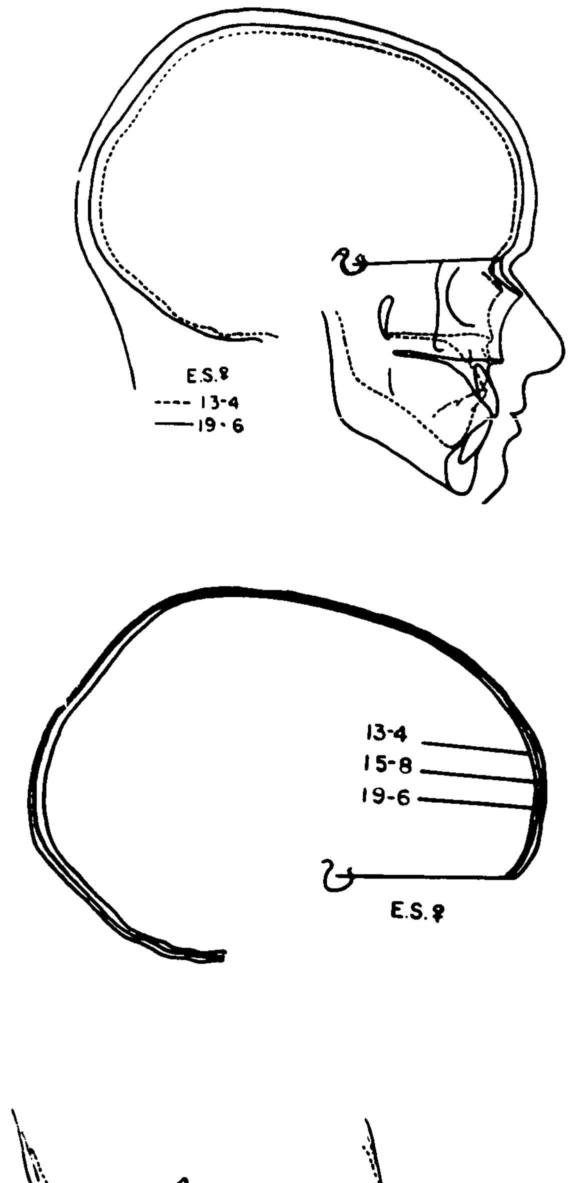

FIG. 4. Superposed tracings of the lateral roentgenograms, cranial composites and mandibular composites of a treated hypothyroid, E. S.

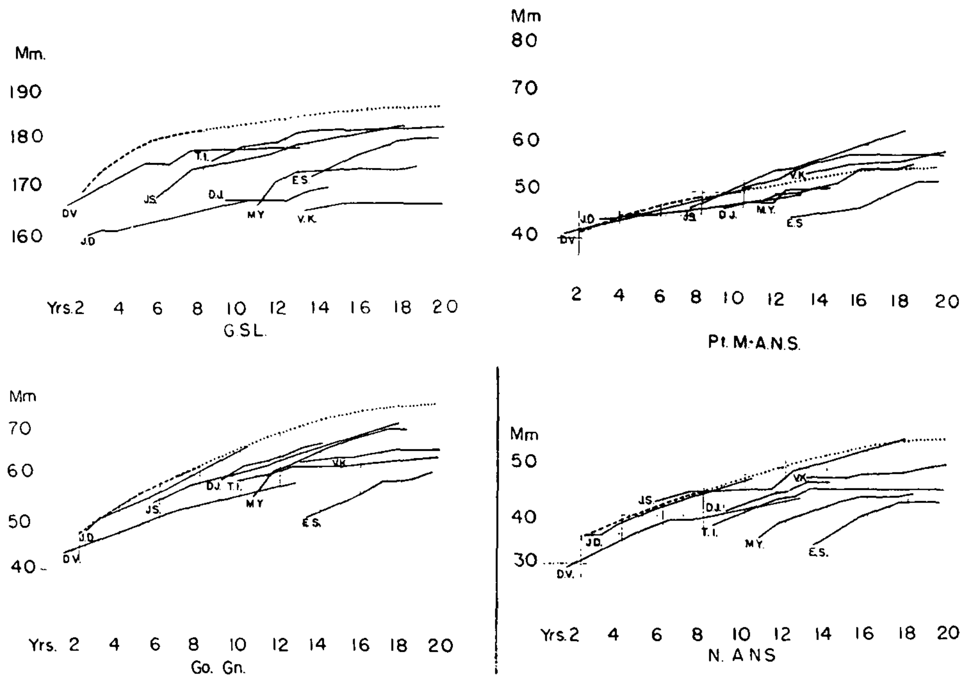

FIG. 5

FIG. 5. The graphs of the measurements of Nasion to the anterior nasal spine, pterygo-maxillary fissure to the anterior nasal spine, Gonion to Gnathion and the greatest skull length for each case were plotted. They were compared to the control curves obtained from Brodie (2). The control is represented by broken line for the actual figures and a dotted line for the extrapolated portion.

The conclusions drawn from this study were:

1. The craniofacial area responded to treatment in thyroid deficient children:
   a) Those who had received consistent and early therapy showed growth curves which very closely approximated the increment and level of those of normal children.
   b) Inadequate and/or late therapy resulted in development which did not attain the levels of the above group.
2. The cranio facial growth pattern followed a definite schedule which could not be extended appreciably by thyroid therapy.
3. Angular measurements indicated little if any variation in the pattern of the treated thyroid deficient child.
4. The longitudinal study of physical development and of physiologic age of the individuals were correlated with craniofacial development.
5. Retarded carpal ossification patterns of the treated typothyroids responded rapidly regardless of age.

Although we were dealing with an endocrine disturbance, these data, with perhaps slight exceptions, confirm most of the conclusions reached in earlier studies (Brodie et al) of normal growth, that there is a tendency for the craniofacial patterns, as determined by the analysis of some significant angles, to remain fairly constant.

808 S. Wood St.

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EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

Allan G. Brodie

(Cont. from p. 38)

In some of our early studies on the changes that occurred with and subsequent to orthodontic management we had become aware of the fact that we were not taking headplates frequently enough and we had been attempting to remedy this shortcoming. By 1945 we had collected enough material to enable us to examine more critically certain aspects of treatment that had been obscure in our earlier work. One of these problems was what actually happened in the change of molar relationship in the treatment of Class II. While we were claiming a distal movement of maxillary molars we were becoming more uncertain that this always occurred and Dr. Robert B. Hedges was assigned this as a thesis subject.

Change In Molar Relationship In Class II, Division 1 Treatment[1]

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In order to comprehend the problems of treatment in Class II division I malocclusions we must first review just what the classification means, the relationship the component parts bear to each other, and the present methods of correcting these relationships.

The introduction by Edward H. Angle of his Classification of Malocclusion[2, 3] in 1899 is generally conceded to be the beginning of scientific thought in orthodontia. The basis of this classification was the relationship of the mandibular teeth to the maxillary teeth. In defining Class II he stated:

> "Class II — Relative mesio-distal relations of the dental arches abnormal; all the lower teeth occluding distal to normal, producing very marked inharmony in the incisive region and in the facial lines.
>
> "Of this class there are two divisions, each having a subdivision. The first division is characterized by a narrowing of the upper arch, lengthened and protruding incisors, accompanied by an abnormal function of the lips and some form of nasal obstruction and mouth breathing.

Angle's use of the words "dental arches" caused a great controversy to arise, many believing that he meant the teeth alone. He later explained[4] that the classes were based on the mesio-distal relations of the *teeth, dental arches, and jaws* as indicated by the mesio-distal position assumed by the first permanent molars upon their eruption. He went on to say that the loss of other teeth by extraction might be followed by changes in the position of these key teeth. When such was the case it would be necessary to determine the amount of such movement before classifying the case.

The controversy continued, however, because it was claimed that the Class II molar relation could be the result of any one of three conditions, namely, a distal positioning of the lower, a mesial position of the upper, or an equal and opposite displacement of both.

In 1928 Oppenheim,[17] using accepted anthropometric technics on a large sample of dried skulls, reached the conclusion that in Class II, with few exceptions, the anomaly was not located in the maxilla. The entire face was shown to be in a more posterior position, the mandible being most affected. In a similar investigation, Hellman[16] arrived at the same conclusions, viz; that the face was smaller in all dimensions, the mandible being most affected.

In 1939 Adams,[1] employing a cephalometric roentgenographic method, demonstrated that there were no essential differences in the morphology or in the absolute dimensions of the mandible in Class I (control) and Class II cases. In 1940 Elman[15] sought to determine whether there was anything unusual in the relationship that the lower molar might bear to the mandible in these cases. By the use of cephalometric roentgenograms he made linear measurements from the first molar to lines tangent to the posterior and inferior borders of the mandible. These measurements he found to be in the approximate ratio of 3/2 in both Class I and Class II cases and that this was true not only prior to but after the molar had come into occlusion.

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1 Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Illinois, 1946.

Baldridge,[8] in 1941, made a similar investigation on the angular relationship of the upper molar to the face and cranium. His results showed that the upper molar bore a constant relationship to the face and cranium, and that the chin point was in a posterior relationship to the face and cranium in Class II Division 1 malocclusions.

In 1942 Brodie[13] published results of a longitudinal study of growing children. He showed that the upper molar descended on a nearly vertical path until it met its antagonist in occlusion. At this time it was found on a line drawn from the center of sella turcica to the chin point (Y axis of growth). The molar maintained its position on this line during the remaining downward and forward growth of the face.

In the light of these investigations it seems apparent that the Class II Division 1 malocclusion is one in which the maxillary molars are in the proper anteroposterior relation to the face and cranium. The lower molars likewise are in proper relation to the mandible. The malrelation of the teeth, therefore, is a reflection of a distal relation of the mandible to the maxilla.

In the clinical treatment of this type of malocclusion many empirical methods have been employed. Most appliances in use during the past half century have had an analagous basic counter-part in the development of various mechanisms by Angle. For this reason a description of his thought will give a picture of the present day procedure in the treatment of these cases. Extraction of two first bicuspids in the maxillary arch followed by the retraction of the protruding anteriors was one of the first plans of which there is record. This changed the facial profile but did not improve the occlusion nor provide a balance of facial parts. Angle adhered to this plan until 1899 when he introduced his classification. The next method was that of Kingsley,[18] who advocated 'jumping the bite'. Each arch was aligned to reduce the protrusion, after which the mandible was moved forward to its anteroposterior relationship by the mechanical action of an inclined plane. This method seemed to show good results, but difficulty arose in holding the relationship after the plane was removed. It is interesting to note that variations of this idea are currently being used. The next step was Baker's introduction of intermaxillary anchorage. Rubber bands were used as a source of force between the anterior portion of the maxillary arch and the posterior portion of the mandibular arch. This reciprocal action seemed to offer a means of establishing proper occlusal relations of the teeth. Tipping of the molar teeth by the action of the elastic bands was expected, but it was hoped that the forces of mastication would gradually induce their uprighting. In this, clinical tests brought disappointment for although the maxillary teeth did gain a more upright position the mandibular teeth did not recover. By 1906 Angle had abandoned all hope of moving the mandibular teeth forward in anything but an undesirable tipped position. He now turned all of his attention to moving the maxillary teeth backward to their correct occlusal relationship as indicated by the following quotation:

> "Now why should we move the upper molars distally if they are in their normal positions in these cases? Simply to do the best we can to strike a balance between the normal in the upper and the abnormal in the lower."[3]

The clinical results obtained by this method of treatment were the best thus far and were stable. His reasoning on this success is revealed in the following words:

> "The mandible, being undersized through the perversion of forces, the movement of the teeth, if limited to the lower, would compel them to lean forward at too great an angle, while by dividing the movements between the teeth of the opposite arches this is prevented, and Nature, being assisted and stimulated through the correct distribution of force upon the teeth and normal function of the muscles, is enabled to normally develop the mandible and all other tissues involved. Through the stimulus thus given it is quite probable that in time the teeth of the upper arch will regain their normal relations to the skull."[4]

These conclusions were based on clinical experimentation done with the simple 'E' arch. This consisted of bands on the four first molars and two labial arches. The remaining teeth in each dental arch were ligated to the 'E' arch by means of soft brass wire. The ligated teeth did not provide stable control, and when the elastic bands were worn the lowers still exhibited an undesirable amount of forward tipping.

Control of root movement was first introduced by Angle in 1910-11[5] when he developed the Pin and Tube appliance. The bands which were placed on the anterior teeth carried vertically disposed tubes which received pins from the arch. Thus, if a tooth moved, it moved in a bodily or translatory manner. This was followed in 1917[6] by the Ribbon Arch appliance and in 1928[7] by the Edgewise Arch mechanism. Each of these appliances afforded better control over individual tooth movements but did not alter the basic principles of treatment in Class II division 1 malocclusions.

It was assumed by all clinicians employing these appliances and these principles of treatment that the resulting changes seen in the occlusal relationships were brought about by the posterior movement of the maxillary teeth. In 1938,[14] the staff of the Department of Orthodontia, University of Illinois published the results of a roentgenographic survey of treated cases in which the above mentioned appliances had been employed. Many startling and unexpected conditions were revealed in regard to the behavior of the entire denture but the long intervals between the taking of the records made impossible any statement regarding the behavior of individual teeth.

The present investigation was undertaken in an effort to elucidate the behavior of the upper and lower first permanent molars under this type of orthodontic management.

Methods and Materials

The material upon which this study was made was taken from 204 cephalometric roentgenograms. 120 of these roentgenograms constituted a control series and were of fourteen untreated growing individuals between the ages of six and twenty-one years. These were selected as growth series without regard to occlusion. Six of the series were from the files of the Bolton Foundation at Western Reserve University and eight of the series were from the files of the Department of Orthodontia, University of Illinois.

Eighty-four roentgenograms from the files of the clinic patients of the Department of Orthodontia, University of Illinois represent twenty-three orthodontically treated individuals. A list of all Class II division 1 cases completed prior to 1944 was selected in the order of the greatest number of roentgenograms for each individual. From this list were selected only cases representing typical Class II division 1 malocclusion with all teeth present. All were treated according to the writings of Angle, Brodie, and Wright on the use of the edgewise arch and by the graduate students in the Department of Orthodontia, University of Illinois. All roentgenograms had been taken on the Broadbent-Bolton roentgenographic cephalometer according to the standard technic described elsewhere in the literature.[9]

Each roentgenogram was traced and certain landmarks located. Lines were drawn on the tracings between various points representing these landmarks. The points and lines used in the study are illustrated in Fig. 1.

1. S-N, a line connecting the center of sella turcica with nasion.
2. S-$\underline{6}$, a line connecting the center of sella turcica with a point representing the buccal grove of the maxillary first permanent molar.
3. S-Gn, a line connecting the center of sella turcica with gnathion. (The anatomical landmark gnathion is determined by bisecting the distance between the most anterior and inferior points of the bony chin.)
4. S-$\overline{6}$, a line connecting the center of sella turcica with the point representing the distal contact point of the mandibular first permanent molar.

The following angles formed by these lines were measured with a transparent protractor to within 0.3 of a degree. These angles are illustrated in Fig. I.

1. Angle N-S-$\underline{6}$, nasion — sella turcica — maxillary first permanent molar.
2. Angle N-S-Gn, nasion — sella turcica — gnathion.
3. Angle N-S-$\overline{6}$, nasion — sella turcica — mandibular first permanent molar.

On the first and last tracings of the treated cases certain additional lines were drawn for the purpose of determining correlations during treatment. These lines are illustrated in Fig. I.

1. Mandibular border—a line tangent to the inferior border of the mandible.
2. Occlusal plane—a line from the incisal edge of the mandibular first incisor to the tip of the most superior cusp of the mandibular first permanent molar.
3. Frankfort plane—a line from porion to left orbital.
4. Perpendicular A—a line perpendicular to the mandibular border and tangent to the most anterior point of the bony chin.
5. Perpendicular M—a line perpendicular to the mandibular border dropped from the distal contact point of the mandibular first permanent molar.

The angular relations between the following were measured by means of a universal drafting machine.

1. Frankfort plane to mandibular border.
2. Occlusal plane to mandibular border.

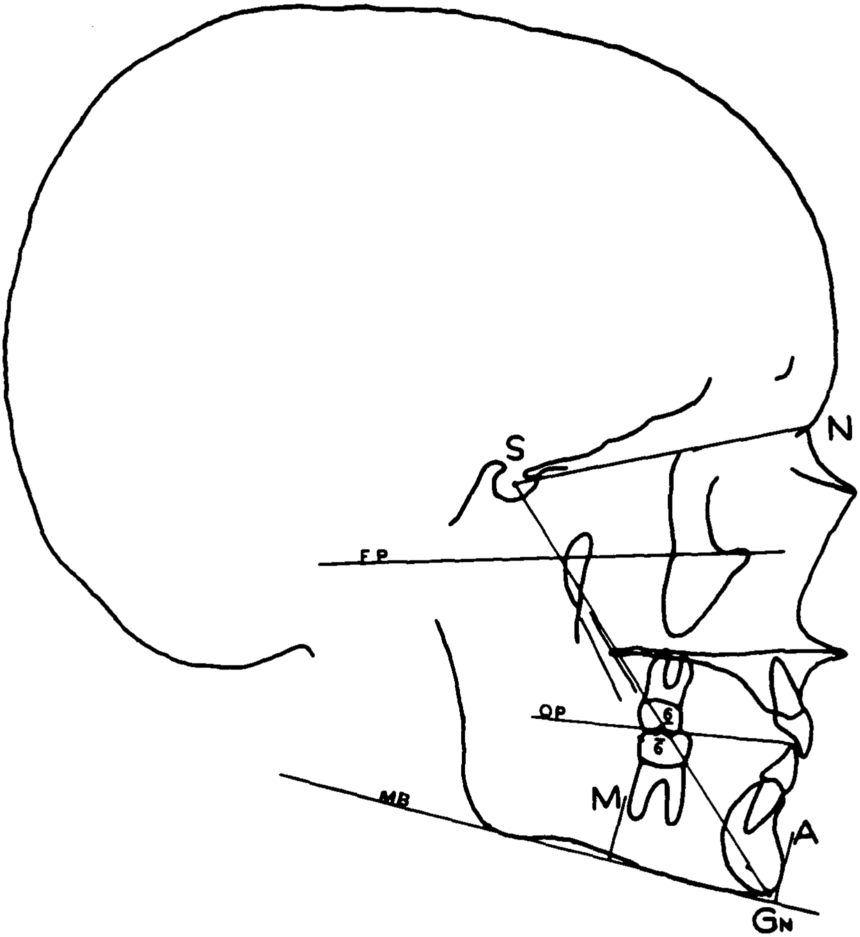

FIG. 1. Showing a typical tracing used in the study, with planes and angles drawn in.

For the purpose of determining (1) growth of the mandible, and (2) changes in the relation of the lower molar to its base in the same individual, the following measurements were made: (Fig. 2)

1. Length of the mandible—the distance between perpendicular A and perpendicular A′ when mandibular lower and posterior borders are superposed. (Fig. 2a)
2. Movement of $\overline{6}$—the distance between perpendicular M and perpendicular M′ when mandibular lower borders and perpendiculars A and A′ are superposed. (Fig. 2b)

FINDINGS

Control Series

The shortest series of records on any individual extended from the eleventh to the fifteenth year and consisted of seven roentgenograms. The longest series extended from the age of eight to twenty-one years and included eleven roentgenograms. The fourteen individuals had a total of 120 roentgenograms.

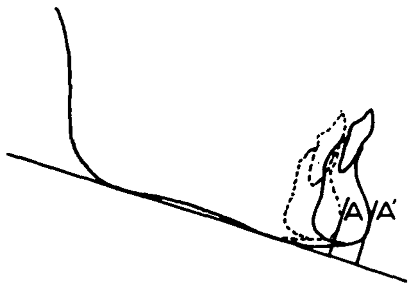

FIG. 2a

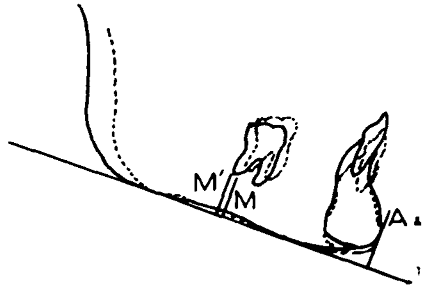

FIG. 2b

Superpositions used to show (left) growth in lower border of mandible; (right) changes in relation of lower molar to base. (See text).

The angle N-S-Gn was found to vary with the individual from a low of 63.3° in one case to a high of 76.7° in another. The angle was found to be highly constant in each individual, however.

Since the line N-S is a common side to the three angles measured (N-S-$\underline{6}$, N-S-$\overline{6}$, N-S-Gn), the smaller angle may be subtracted from the larger and the variations of the angles N-S-$\underline{6}$ and N-S-$\overline{6}$ from the angle N-S-Gn may be determined. The angle N-S-$\underline{6}$ shows a minimum variation from N-S-Gn of 0.6° and a maximum variation of 7.4°. The angle N-S-$\overline{6}$ shows a minimum variation from N-S-Gn of 1.1° and a maximum variation of 8.8°. (Both maximum variations occurred prior to full eruption of the first permanent molars.) By elimination of one roentgenogram in each series, the maximum variation of N-S-$\overline{6}$ from N-S-Gn can be reduced to 3.1° and that of N-S-$\underline{6}$ from N-S-Gn reduced to 5.8°. The minimum variations were in the same individual while the maximum variations were in different ones.

Although the upper first permanent molar is carried downward and forward with the growth of the face, it appears to maintain a constant relation to the line S-Gn after it comes into occlusion with its antagonist. Prior to this time, or during its active eruptive stage, it drops straight down. Thus the angle N-S-$\underline{6}$ gradually increases until occlusion is established; thereafter it is constant.

Treated Cases

The same lines as were used on the tracings of the control series were drawn in on all tracings of the twenty-three treated cases and the angles N-S-$\underline{6}$, N-S-$\overline{6}$, and N-S-Gn were tabulated. Since it had been shown that the molars bore a definite relation to the line S-Gn in untreated cases, various groupings were made.

In eleven of the twenty-three treated cases the angle N-S-Gn remained constant. In nine of these cases the upper first molar remained in the same angular relation to the line S-Gn, although proceeding downward and forward in the same manner as shown by the control. The lower first molar moved forward in relation to the upper and in relation to the line S-Gn, establishing a Class I relationship. In the remaining two cases the upper first molar was revealed to have moved backward in relation to the line S-Gn and the lower had moved forward in the same relation.

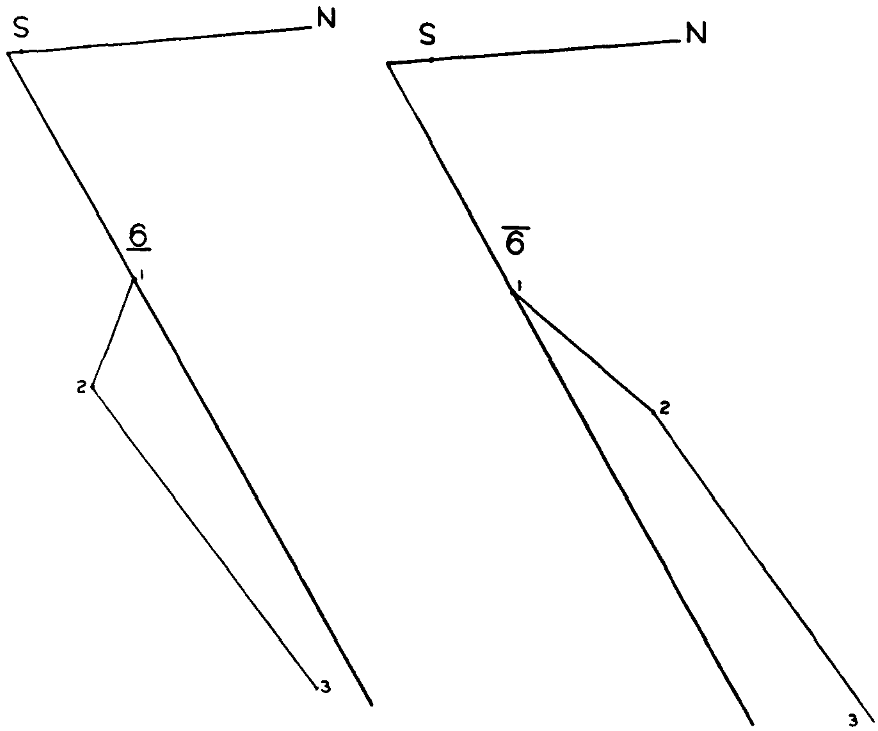

FIG. 3a

Age	N-S-6	N-S-$\bar{6}$	N-S-Gn
10-8-19	67.1	74.8	65.2
12-6-9	70.2	73.1	65.8
16-7-11	68.0	70.1	65.0

In another group of eleven treated cases the angle N-S-Gn was found to have opened or increased. In eight of these the upper molar had remained constant and the lower had gone forward in relation to the line S-Gn. In two cases the upper and lower had both moved forward, the lower more than the upper. In one of these cases the upper molar had moved backward and the lower had remains constant in relation to the line S-Gn.

In only one of the treated cases was the angle N-S-Gn found to have closed or decreased. This case showed the upper molar to have gone backward in relation to the line S-Gn while the lower remained constant to the line.

Since the molars had been shown to bear a definite angular relationship to the line S-Gn in the control series, a grouping was made showing the angular variations of the molars from the line S-Gn in the treated cases. Seventeen cases showed the upper molar to have remained constant to the line S-Gn while the lower molar showed a more forward relation. Two cases showed the upper molar in a more posterior position in relation to the line S-Gn while the lower showed a more forward position. Two cases showed the upper molar in a more posterior position in relation to the line S-Gn while the lower molar maintained a constant relation to the line. The last two cases showed both the upper and lower molars in a more forward position in relation to the line S-Gn, the lower showing a greater variation from its original position.

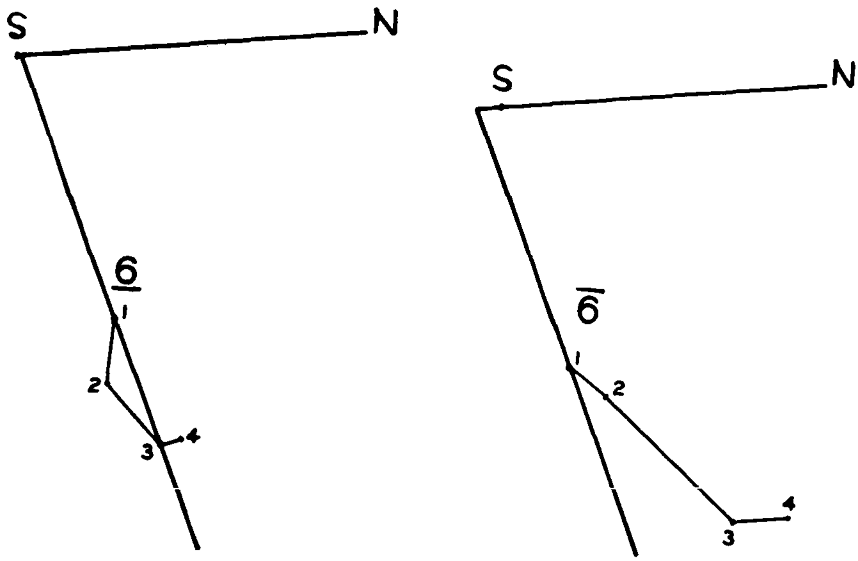

FIG. 3b

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
10-4-6	73.5	79.0	74.0
11-8-11	76.3	80.7	76.1
15-7-13	75.0	77.1	75.7
17-3-27	74.7	77.5	75.8

Because of the number of cases showing a forward repositioning of the lower molar in space i.e., when superposing on S-N, it was necessary to determine how much of this change was due to (1) shifting of the mandible, (2) growth of the mandible, and (3) movement of the lower molar within the mandible. In thirteen cases, the growth of the mandible was seen to be of considerable amount while the forward movement of the molar within this bone was slight or none. In four cases the growth of the mandible was in an amount equal to that of the forward movement of the lower molar. One case showed little or no growth of the mandible, but the molar was seen to have moved forward to a considerable extent. The five remaining cases exhibited no appreciable mandibular growth or forward movement of the molar.

In order to determine whether any correlation existed between the change in relationship of the molars to the line S-Gn and the changes observed in the mandible, a cross grouping was made and is shown in Table I.

The following additional measurements were made but yielded no significant changes:

1. Angular change occlusal plane to mandibular border.
2. Months of active treatment.
3. Angle of Frankfort plane to mandibular border at the beginning of treatment.
4. Angular change of Frankfort plane to mandibular border during treatment.

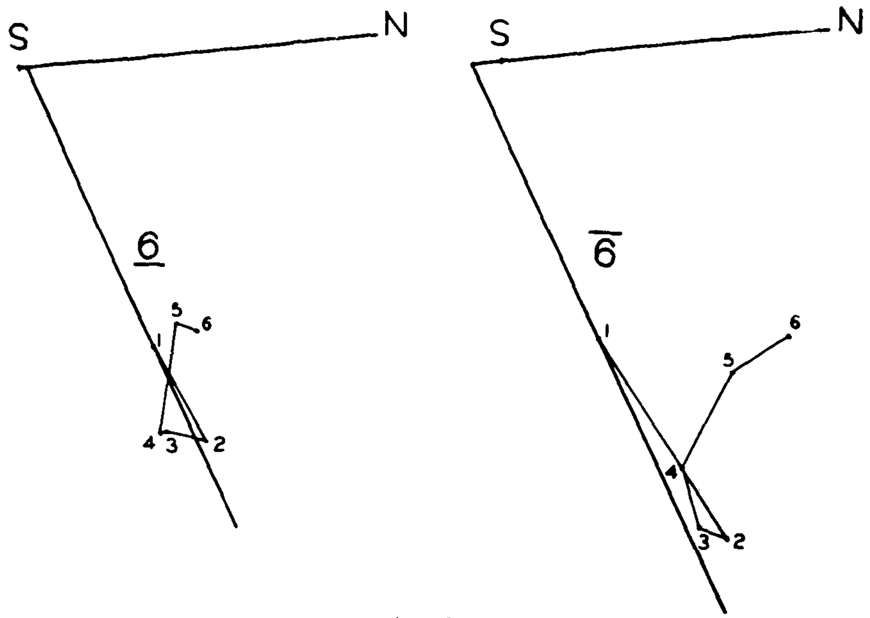

FIG. 3c

Age	N-S-6	N-S-$\overline{6}$	N-S-Gn
14.1-23	69.5	76.2	70.5
14-7-3	69.0	74.8	70.2
15-1-4	71.1	76.7	71.8
15-5-6	70.9	76.3	71.5
16-9-25	71.0	75.9	72.6
18-7-6	70.8	74.9	72.4

DISCUSSION

In a study employing longitudinal measurements the factor of human error has greater significance than in a cross sectional study where the results are expressed in terms of means. This is particularly true in a measurement of angles on consecutive tracings of roentgenograms of the same individual. Here the slightest difference in head position may change the position of an anatomical landmark. The raw data obtained from consecutive tracings must be interpreted in the light of evidence derived from various superpositionings of the tracings. In this study a temporary angular variation of 2.0° was considered to be a constant provided the variation did not show a trend in either direction. When a trend appeared, however, it was considered to be significant if only of 1.0°.

Of the seventeen cases in which $\underline{6}$ remained constant and $\overline{6}$ was found to be forward of its original position, eleven showed considerable mandibular growth and slight or no forward movement of the tooth within the bone. Seven of this first group of eleven showed a constant angle N-S-Gn. Typical behavior is shown in Fig. 3a. Four cases of this first group of eleven showed an increase of the angle N-S-Gn and a typical case of this category is shown in Fig. 3b. Both of these cases show, as do most of the cases studied, an initial posterior tipping of the upper molar, but this tooth regains its original axial inclination after engaging in the proper inclined plane relation. It must be realized that when the angle N-S-Gn increases, the

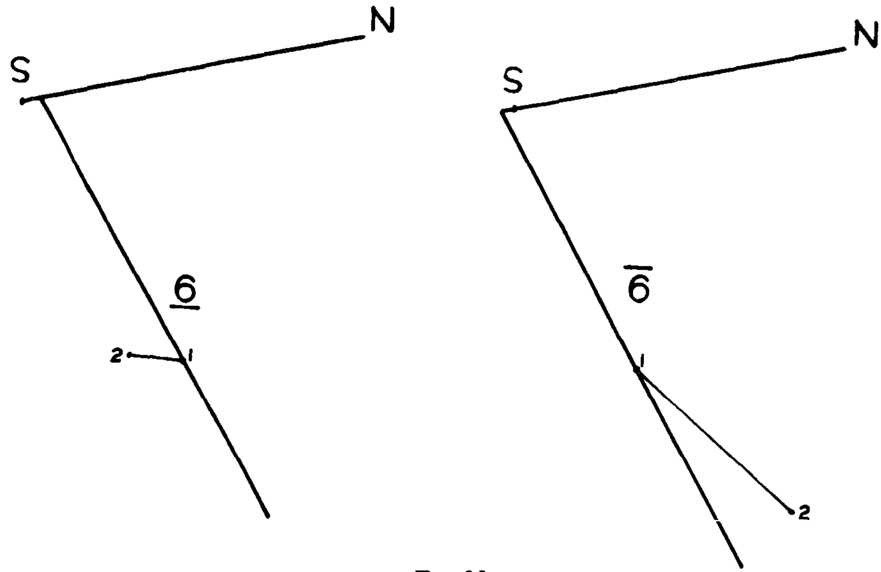

FIG. 3d

Age	N-S-6	N-S-$\overline{6}$	N-S-Gn
12-5-10	68.9	74.8	71.8
15-3-27	71.2	74.3	73.1

molar must also be further back if it retains its original relation to this line. The three cases of the second group in the first column of Table I in which mandibular growth and forward movement of the molar were of equal amounts presented pictures essentially the same as those seen in the first group. Two of the three cases showed the angle N-S-Gn to open while it remained constant in one. In the third group of column one there is one case showing slight mandibular growth and considerable forward movement of the lower molar within the mandible. The end results give the same picture as seen in the first two groups, but the paths followed by the molars in this case are rather interesting. Fig. 3c illustrates these paths. It is noted that this case was under active treatment for thirty-one months and that there was an 8.0° change in the occlusal plane. This was a greater than average change. In two cases in which it was shown that the change in molar relationship was brought about entirely by forward movement of the lower molar in space without appreciable growth or change in its relation to the mandible, a problem was presented that was difficult to explain. Figure 3d shows the molar paths in one of these cases. The outstanding change in this case is the 11.0° tipping of the occlusal plane. Since Brodie, Downs, Goldstein, and Myer in 1938[14] showed that the change in occlusal plane during treatment tends to return toward its original level after treatment, it is conceivable that a subsequent roentgenogram would show this tendency and present a pattern similar to the preceding ones.

In the second type of molar movement $\underline{6}$ is shown to go posteriorly while $\overline{6}$ goes anteriorly in relation to the line S-Gn. This is shown in Fig. 4 and is the case in which mandibular growth and forward movement of the molar is negligible. Here again there is a shifting of the occlusal plane of 9.3°. The other case of this type presented relatively the same picture, but the growth changes are quite marked. It is significant that in both of these cases the angle N-S-Gn had remained constant.

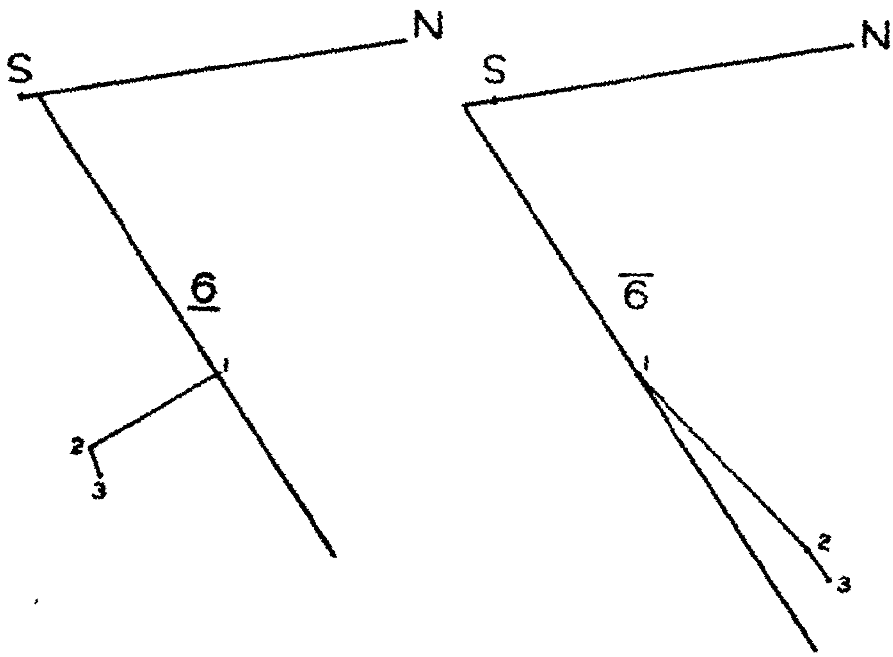

Fig. 4

Age	N-S-6	N-S-$\overline{6}$	N-S-Gn
12-9-10	63.4	72.0	66.8
14-4-15	66.0	70 8	66.5
15-3-5	66.0	70 8	66.8

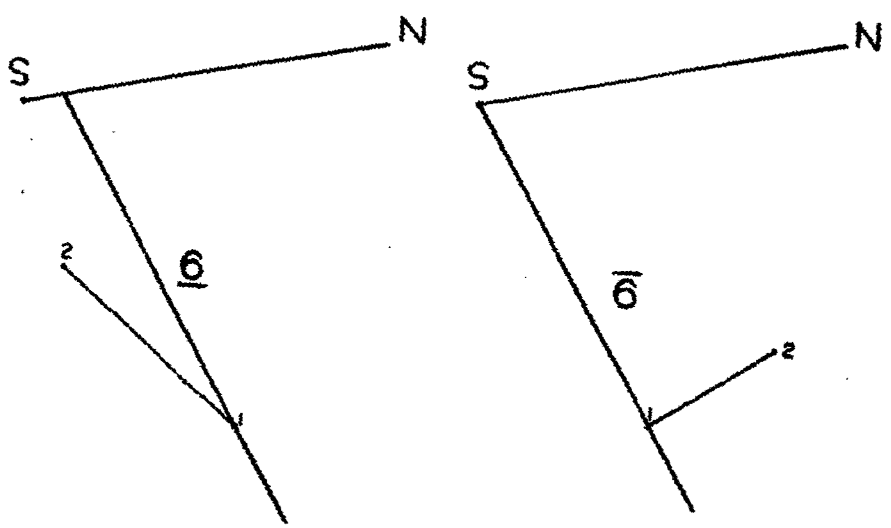

Fig. 5

Age	N-S-6	N-S-$\overline{6}$	N-S-Gn
20-11-3	66.1	71.8	71.8
24-8-20	68.7	71.1	73.7

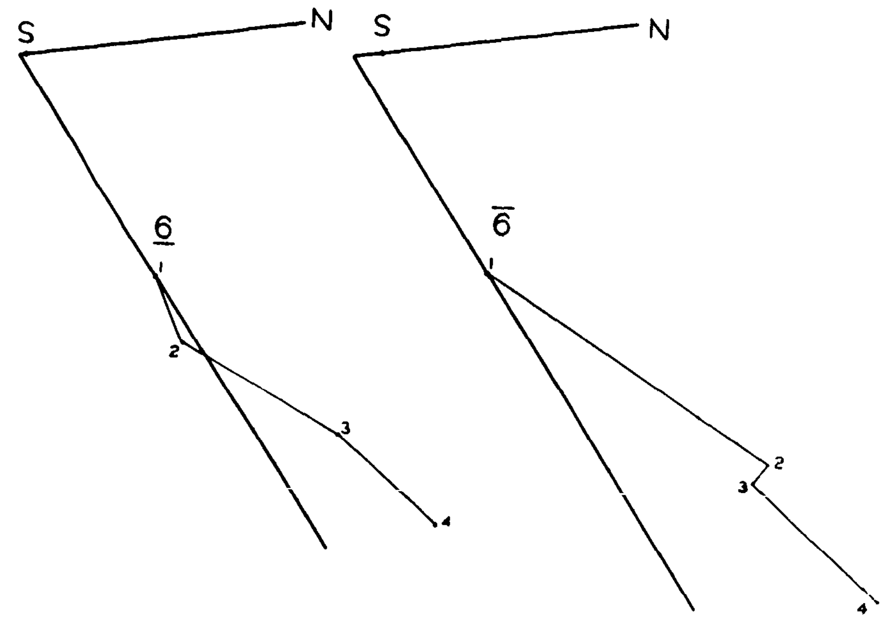

FIG. 6

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
11-7-5	65.9	70.8	64.5
13-3-19	66.5	67.8	65.1
15-3-27	66.0	69.7	66.9
16-10-14	65.8	69.3	67.2

In the third type of molar change $\overline{6}$ is apparently constant to S-Gn and $\underline{6}$ has been moved posteriorly. The first of the two cases in this category showed a decrease of the angle N-S-Gn and is the only case out of the twenty-three studied which showed such a decrease. This can easily be accounted for when the tracings are superposed and the large amount of growth in the anterior direction is observed. The other case of this type is one in which growth was negligible, and the angle N-S-Gn had increased. However, there was a shifting of the occlusal plane of 10.6°. This case is diagrammed in Fig. 5. If vertical growth had been the equivalent of anterior growth, in the former of the two cases, the angle N-S-Gn would have remained constant. Under these circumstances the pattern obtained would have been similar to that seen in the first type (Column 1 — Table I). In the second case, however, the angle N-S-Gn increased due to a tipping of the occlusal plane. Had the angle N-S-Gn remained constant here, the pattern would have been more exaggerated. It would have shown a greater posterior tipping of the upper molar. This can be seen by superposing of the tracings. The behavior of this case can be accounted for by the fact that the patient was beyond the age where significant growth is expected.

The remaining two cases show a fourth type of molar change in which both molars are in a more forward position. Both cases showed an increase of the angle N-S-Gn, but one showed a negligible amount of growth and a negligible amount of forward movement of the molar in relation to the mandible. This case does not show a marked improvement of the molar relationship and the clinical result is poor. The other case, which is diagrammed in Fig. 6, showed good growth as well as an equivalent amount of forward positioning of the lower molar. Growth apparently accounts for the mesial relation of both molars to the line S-Gn.

The two most constant observations on the clinically successful cases were (1) a tendency for the lower molar to be repositioned in a more forward relationship to the line S-Gn without significant change in its relation to the mandible, and (2) a tendency for the upper first molar to show an initial posterior relation to the line S-Gn. Subsequent records indicate a tendency for the upper molar to regain its original relation with the line S-Gn without disturbance of the normal intermolar relation obtained by treatment.

CONCLUSIONS

1. In untreated cases, the upper and lower first permanent molars bear a definite and constant angular relationship to the line S-Gn in the individual.
2. The angle N-S-Gn increases in approximately one-half of the treated cases. In the other half it remains constant.
3. The angular relationship between the first permanent molars and the line S-Gn is altered in the treatment of Class II Division 1 malocclusions.
4. In the majority of cases the lower first permanent molar shows a forward positioning in relation to the line S-Gn.
5. The majority of cases show a constant relation of the upper first permanent molar to the line S-Gn. There is an initial posterior tipping of the upper first permanent molar but the axial inclination of the molar is regained eventually. During the period of posterior tipping, the face is growing downward and forward.
6. Mandibular growth accounts for the major amount of change in molar relationship.
7. Treatment accompanied by little or no growth appears to cause a change in the facial pattern as observed by the tipping of the occlusal plane.

TABLE I

	6—Const. 6—For.	6—Back. 6—For.	6—Back. 6—Const.	6—For. 6—For.
Mand. Gro. Great For. Molar Move. Sl. or None	11	1	1	
Mand. Gro. Equal to For. Molar Move.	3			1
Mand. Gro. Sl. or None For. Molar Move. Great	1			
Mand. Gro. Neg. For. Molar Move. Neg.	2	1	1	1

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703 WEST AVENUE

EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

ALLAN G. BRODIE

(Cont. from p. 44)

As you can see our fears were justified. The successfully treated Class II malocclusion may result from a number of different phenomena and apparently, in this sample at least, the distal movement of maxillary molars occurs less frequently than almost any other movement.

In 1936 we had seen the results of Oppenheim's head-cap treatment in Vienna and upon our return had tried it on some of our clinical cases, but only in a half-hearted manner. When he came to this coutry, however, interest in this method of treatment revived and his visit to the department in 1945 kindled considerable interest in it. Dr. Myer undertook the treatment of a number of cases with this method and took very careful records in order to determine exactly what changes occurred under this method of treatment. By 1946 we had collected enough material to make preliminary appraisal possible. Dr. Walter Epstein undertook this appraisal and his thesis will be the next one to be incorporated into this review of eighteen years of research at Illinois.

Change In Molar Relationship In Class II, Division 1 Treatment[1]

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In order to comprehend the problems of treatment in Class II division I malocclusions we must first review just what the classification means, the relationship the component parts bear to each other, and the present methods of correcting these relationships.

The introduction by Edward H. Angle of his Classification of Malocclusion[2, 3] in 1899 is generally conceded to be the beginning of scientific thought in orthodontia. The basis of this classification was the relationship of the mandibular teeth to the maxillary teeth. In defining Class II he stated:

> "Class II — Relative mesio-distal relations of the dental arches abnormal; all the lower teeth occluding distal to normal, producing very marked inharmony in the incisive region and in the facial lines.
>
> "Of this class there are two divisions, each having a subdivision. The first division is characterized by a narrowing of the upper arch, lengthened and protruding incisors, accompanied by an abnormal function of the lips and some form of nasal obstruction and mouth breathing.

Angle's use of the words "dental arches" caused a great controversy to arise, many believing that he meant the teeth alone. He later explained[4] that the classes were based on the mesio-distal relations of the *teeth, dental arches, and jaws* as indicated by the mesio-distal position assumed by the first permanent molars upon their eruption. He went on to say that the loss of other teeth by extraction might be followed by changes in the position of these key teeth. When such was the case it would be necessary to determine the amount of such movement before classifying the case.

The controversy continued, however, because it was claimed that the Class II molar relation could be the result of any one of three conditions, namely, a distal positioning of the lower, a mesial position of the upper, or an equal and opposite displacement of both.

In 1928 Oppenheim,[17] using accepted anthropometric technics on a large sample of dried skulls, reached the conclusion that in Class II, with few exceptions, the anomaly was not located in the maxilla. The entire face was shown to be in a more posterior position, the mandible being most affected. In a similar investigation, Hellman[16] arrived at the same conclusions, viz; that the face was smaller in all dimensions, the mandible being most affected.

In 1939 Adams,[1] employing a cephalometric roentgenographic method, demonstrated that there were no essential differences in the morphology or in the absolute dimensions of the mandible in Class I (control) and Class II cases. In 1940 Elman[15] sought to determine whether there was anything unusual in the relationship that the lower molar might bear to the mandible in these cases. By the use of cephalometric roentgenograms he made linear measurements from the first molar to lines tangent to the posterior and inferior borders of the mandible. These measurements he found to be in the approximate ratio of 3/2 in both Class I and Class II cases and that this was true not only prior to but after the molar had come into occlusion.

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1 Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Illinois, 1946.

Baldridge,[8] in 1941, made a similar investigation on the angular relationship of the upper molar to the face and cranium. His results showed that the upper molar bore a constant relationship to the face and cranium, and that the chin point was in a posterior relationship to the face and cranium in Class II Division 1 malocclusions.

In 1942 Brodie[13] published results of a longitudinal study of growing children. He showed that the upper molar descended on a nearly vertical path until it met its antagonist in occlusion. At this time it was found on a line drawn from the center of sella turcica to the chin point (Y axis of growth). The molar maintained its position on this line during the remaining downward and forward growth of the face.

In the light of these investigations it seems apparent that the Class II Division 1 malocclusion is one in which the maxillary molars are in the proper anteroposterior relation to the face and cranium. The lower molars likewise are in proper relation to the mandible. The malrelation of the teeth, therefore, is a reflection of a distal relation of the mandible to the maxilla.

In the clinical treatment of this type of malocclusion many empirical methods have been employed. Most appliances in use during the past half century have had an analagous basic counter-part in the development of various mechanisms by Angle. For this reason a description of his thought will give a picture of the present day procedure in the treatment of these cases. Extraction of two first bicuspids in the maxillary arch followed by the retraction of the protruding anteriors was one of the first plans of which there is record. This changed the facial profile but did not improve the occlusion nor provide a balance of facial parts. Angle adhered to this plan until 1899 when he introduced his classification. The next method was that of Kingsley,[18] who advocated 'jumping the bite'. Each arch was aligned to reduce the protrusion, after which the mandible was moved forward to its anteroposterior relationship by the mechanical action of an inclined plane. This method seemed to show good results, but difficulty arose in holding the relationship after the plane was removed. It is interesting to note that variations of this idea are currently being used. The next step was Baker's introduction of intermaxillary anchorage. Rubber bands were used as a source of force between the anterior portion of the maxillary arch and the posterior portion of the mandibular arch. This reciprocal action seemed to offer a means of establishing proper occlusal relations of the teeth. Tipping of the molar teeth by the action of the elastic bands was expected, but it was hoped that the forces of mastication would gradually induce their uprighting. In this, clinical tests brought disappointment for although the maxillary teeth did gain a more upright position the mandibular teeth did not recover. By 1906 Angle had abandoned all hope of moving the mandibular teeth forward in anything but an undesirable tipped position. He now turned all of his attention to moving the maxillary teeth backward to their correct occlusal relationship as indicated by the following quotation:

> "Now why should we move the upper molars distally if they are in their normal positions in these cases? Simply to do the best we can to strike a balance between the normal in the upper and the abnormal in the lower."[3]

The clinical results obtained by this method of treatment were the best thus far and were stable. His reasoning on this success is revealed in the following words:

> "The mandible, being undersized through the perversion of forces, the movement of the teeth, if limited to the lower, would compel them to lean forward at too great an angle, while by dividing the movements between the teeth of the opposite arches this is prevented, and Nature, being assisted and stimulated through the correct distribution of force upon the teeth and normal function of the muscles, is enabled to normally develop the mandible and all other tissues involved. Through the stimulus thus given it is quite probable that in time the teeth of the upper arch will regain their normal relations to the skull."[4]

These conclusions were based on clinical experimentation done with the simple 'E' arch. This consisted of bands on the four first molars and two labial arches. The remaining teeth in each dental arch were ligated to the 'E' arch by means of soft brass wire. The ligated teeth did not provide stable control, and when the elastic bands were worn the lowers still exhibited an undesirable amount of forward tipping.

Control of root movement was first introduced by Angle in 1910-11[5] when he developed the Pin and Tube appliance. The bands which were placed on the anterior teeth carried vertically disposed tubes which received pins from the arch. Thus, if a tooth moved, it moved in a bodily or translatory manner. This was followed in 1917[6] by the Ribbon Arch appliance and in 1928[7] by the Edgewise Arch mechanism. Each of these appliances afforded better control over individual tooth movements but did not alter the basic principles of treatment in Class II division 1 malocclusions.

It was assumed by all clinicians employing these appliances and these principles of treatment that the resulting changes seen in the occlusal relationships were brought about by the posterior movement of the maxillary teeth. In 1938,[14] the staff of the Department of Orthodontia, University of Illinois published the results of a roentgenographic survey of treated cases in which the above mentioned appliances had been employed. Many startling and unexpected conditions were revealed in regard to the behavior of the entire denture but the long intervals between the taking of the records made impossible any statement regarding the behavior of individual teeth.

The present investigation was undertaken in an effort to elucidate the behavior of the upper and lower first permanent molars under this type of orthodontic management.

Methods and Materials

The material upon which this study was made was taken from 204 cephalometric roentgenograms. 120 of these roentgenograms constituted a control series and were of fourteen untreated growing individuals between the ages of six and twenty-one years. These were selected as growth series without regard to occlusion. Six of the series were from the files of the Bolton Foundation at Western Reserve University and eight of the series were from the files of the Department of Orthodontia, University of Illinois.

Eighty-four roentgenograms from the files of the clinic patients of the Department of Orthodontia, University of Illinois represent twenty-three orthodontically treated individuals. A list of all Class II division 1 cases completed prior to 1944 was selected in the order of the greatest number of roentgenograms for each individual. From this list were selected only cases representing typical Class II division 1 malocclusion with all teeth present. All were treated according to the writings of Angle, Brodie, and Wright on the use of the edgewise arch and by the graduate students in the Department of Orthodontia, University of Illinois. All roentgenograms had been taken on the Broadbent-Bolton roentgenographic cephalometer according to the standard technic described elsewhere in the literature.[9]

Each roentgenogram was traced and certain landmarks located. Lines were drawn on the tracings between various points representing these landmarks. The points and lines used in the study are illustrated in Fig. 1.

1. S-N, a line connecting the center of sella turcica with nasion.
2. S-$\underline{6}$, a line connecting the center of sella turcica with a point representing the buccal grove of the maxillary first permanent molar.
3. S-Gn, a line connecting the center of sella turcica with gnathion. (The anatomical landmark gnathion is determined by bisecting the distance between the most anterior and inferior points of the bony chin.)
4. S-$\overline{6}$, a line connecting the center of sella turcica with the point representing the distal contact point of the mandibular first permanent molar.

The following angles formed by these lines were measured with a transparent protractor to within 0.3 of a degree. These angles are illustrated in Fig. I.

1. Angle N-S-$\underline{6}$, nasion — sella turcica — maxillary first permanent molar.
2. Angle N-S-Gn, nasion — sella turcica — gnathion.
3. Angle N-S-$\overline{6}$, nasion — sella turcica — mandibular first permanent molar.

On the first and last tracings of the treated cases certain additional lines were drawn for the purpose of determining correlations during treatment. These lines are illustrated in Fig. I.

1. Mandibular border—a line tangent to the inferior border of the mandible.
2. Occlusal plane—a line from the incisal edge of the mandibular first incisor to the tip of the most superior cusp of the mandibular first permanent molar.
3. Frankfort plane—a line from porion to left orbital.
4. Perpendicular A—a line perpendicular to the mandibular border and tangent to the most anterior point of the bony chin.
5. Perpendicular M—a line perpendicular to the mandibular border dropped from the distal contact point of the mandibular first permanent molar.

The angular relations between the following were measured by means of a universal drafting machine.

1. Frankfort plane to mandibular border.
2. Occlusal plane to mandibular border.

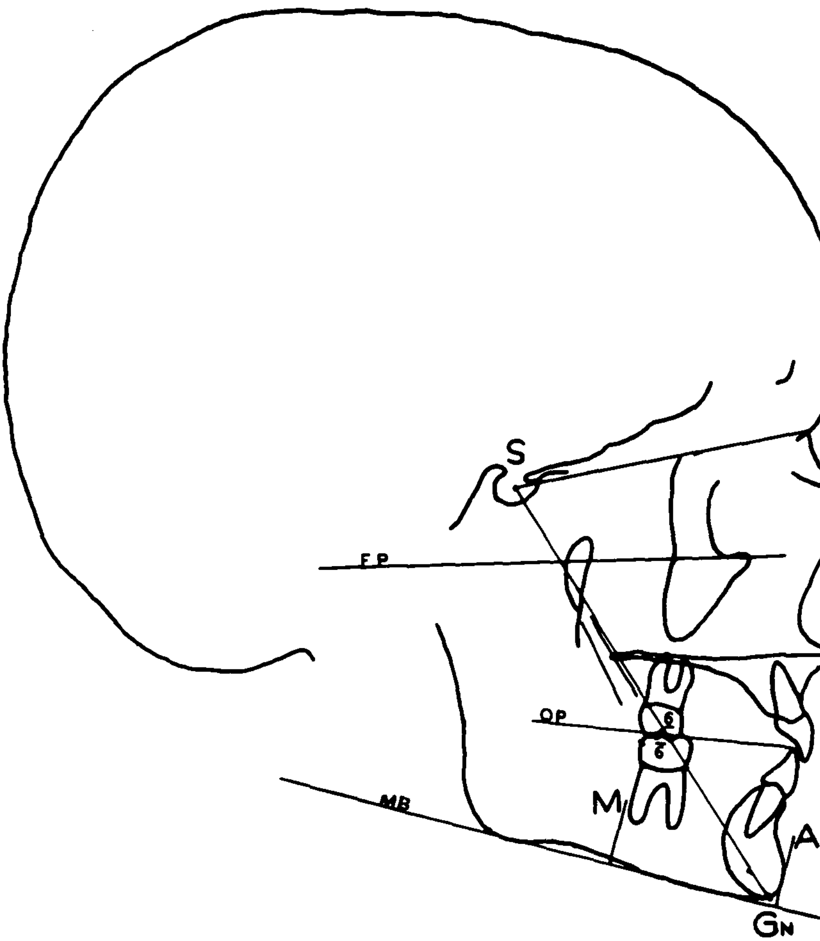

FIG. 1. Showing a typical tracing used in the study, with planes and angles drawn in.

For the purpose of determining (1) growth of the mandible, and (2) changes in the relation of the lower molar to its base in the same individual, the following measurements were made: (Fig. 2)

1. Length of the mandible—the distance between perpendicular A and perpendicular A′ when mandibular lower and posterior borders are superposed. (Fig. 2a)
2. Movement of $\overline{6}$—the distance between perpendicular M and perpendicular M′ when mandibular lower borders and perpendiculars A and A′ are superposed. (Fig. 2b)

Findings

Control Series

The shortest series of records on any individual extended from the eleventh to the fifteenth year and consisted of seven roentgenograms. The longest series extended from the age of eight to twenty-one years and included eleven roentgenograms. The fourteen individuals had a total of 120 roentgenograms.

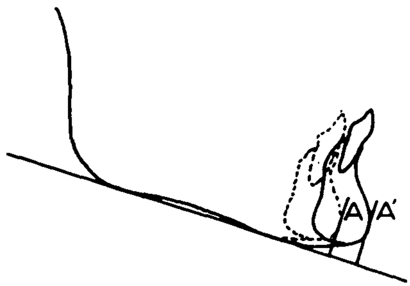

Fig. 2a

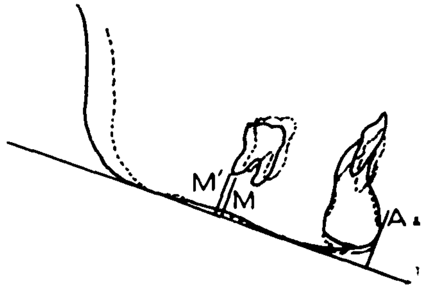

Fig. 2b

Superpositions used to show (left) growth in lower border of mandible; (right) changes in relation of lower molar to base. (See text).

The angle N-S-Gn was found to vary with the individual from a low of 63.3° in one case to a high of 76.7° in another. The angle was found to be highly constant in each individual, however.

Since the line N-S is a common side to the three angles measured (N-S-$\underline{6}$, N-S-$\overline{6}$, N-S-Gn), the smaller angle may be subtracted from the larger and the variations of the angles N-S-$\underline{6}$ and N-S-$\overline{6}$ from the angle N-S-Gn may be determined. The angle N-S-$\underline{6}$ shows a minimum variation from N-S-Gn of 0.6° and a maximum variation of 7.4°. The angle N-S-$\overline{6}$ shows a minimum variation from N-S-Gn of 1.1° and a maximum variation of 8.8°. (Both maximum variations occurred prior to full eruption of the first permanent molars.) By elimination of one roentgenogram in each series, the maximum variation of N-S-$\overline{6}$ from N-S-Gn can be reduced to 3.1° and that of N-S-$\underline{6}$ from N-S-Gn reduced to 5.8°. The minimum variations were in the same individual while the maximum variations were in different ones.

Although the upper first permanent molar is carried downward and forward with the growth of the face, it appears to maintain a constant relation to the line S-Gn after it comes into occlusion with its antagonist. Prior to this time, or during its active eruptive stage, it drops straight down. Thus the angle N-S-$\underline{6}$ gradually increases until occlusion is established; thereafter it is constant.

Treated Cases

The same lines as were used on the tracings of the control series were drawn in on all tracings of the twenty-three treated cases and the angles N-S-$\underline{6}$, N-S-$\overline{6}$, and N-S-Gn were tabulated. Since it had been shown that the molars bore a definite relation to the line S-Gn in untreated cases, various groupings were made.

In eleven of the twenty-three treated cases the angle N-S-Gn remained constant. In nine of these cases the upper first molar remained in the same angular relation to the line S-Gn, although proceeding downward and forward in the same manner as shown by the control. The lower first molar moved forward in relation to the upper and in relation to the line S-Gn, establishing a Class I relationship. In the remaining two cases the upper first molar was revealed to have moved backward in relation to the line S-Gn and the lower had moved forward in the same relation.

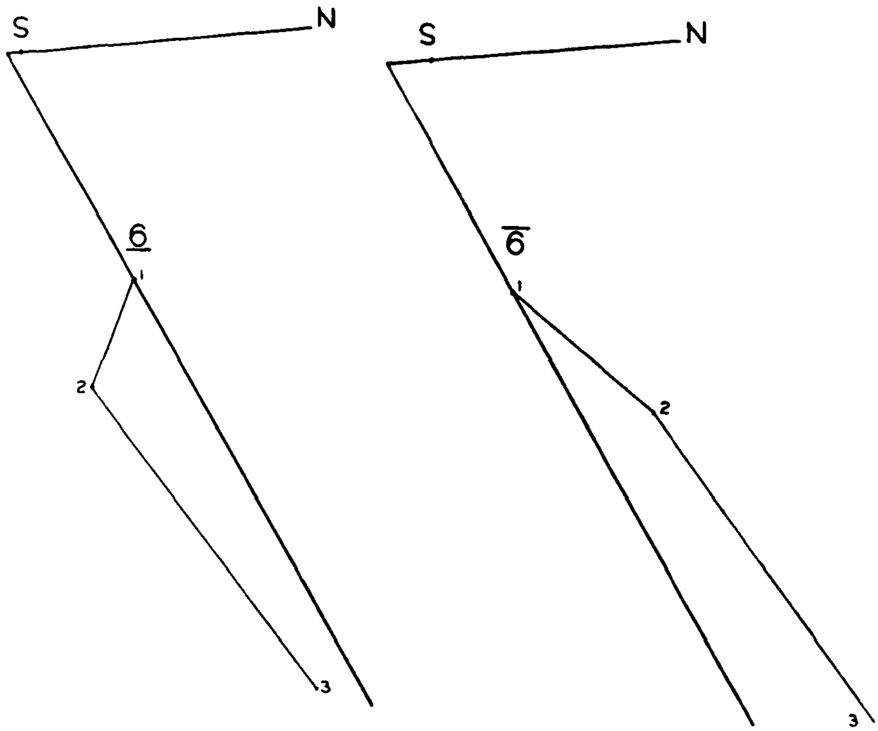

FIG. 3a

Age	N-S-6	N-S-$\bar{6}$	N-S-Gn
10-8-19	67.1	74.8	65.2
12-6-9	70.2	73.1	65.8
16-7-11	68.0	70.1	65.0

In another group of eleven treated cases the angle N-S-Gn was found to have opened or increased. In eight of these the upper molar had remained constant and the lower had gone forward in relation to the line S-Gn. In two cases the upper and lower had both moved forward, the lower more than the upper. In one of these cases the upper molar had moved backward and the lower had remains constant in relation to the line S-Gn.

In only one of the treated cases was the angle N-S-Gn found to have closed or decreased. This case showed the upper molar to have gone backward in relation to the line S-Gn while the lower remained constant to the line.

Since the molars had been shown to bear a definite angular relationship to the line S-Gn in the control series, a grouping was made showing the angular variations of the molars from the line S-Gn in the treated cases. Seventeen cases showed the upper molar to have remained constant to the line S-Gn while the lower molar showed a more forward relation. Two cases showed the upper molar in a more posterior position in relation to the line S-Gn while the lower showed a more forward position. Two cases showed the upper molar in a more posterior position in relation to the line S-Gn while the lower molar maintained a constant relation to the line. The last two cases showed both the upper and lower molars in a more forward position in relation to the line S-Gn, the lower showing a greater variation from its original position.

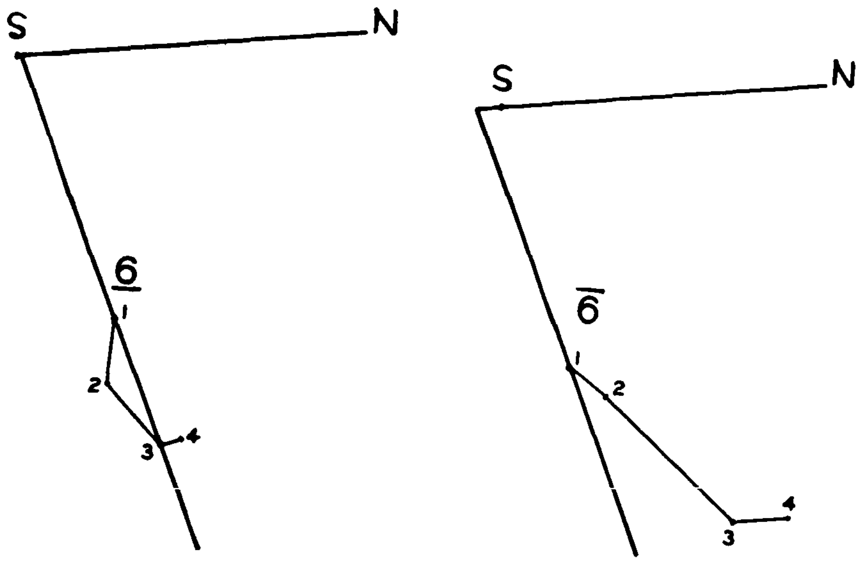

Fig. 3b

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
10-4-6	73.5	79.0	74.0
11-8-11	76.3	80.7	76.1
15-7-13	75.0	77.1	75.7
17-3-27	74.7	77.5	75.8

Because of the number of cases showing a forward repositioning of the lower molar in space i.e., when superposing on S-N, it was necessary to determine how much of this change was due to (1) shifting of the mandible, (2) growth of the mandible, and (3) movement of the lower molar within the mandible. In thirteen cases, the growth of the mandible was seen to be of considerable amount while the forward movement of the molar within this bone was slight or none. In four cases the growth of the mandible was in an amount equal to that of the forward movement of the lower molar. One case showed little or no growth of the mandible, but the molar was seen to have moved forward to a considerable extent. The five remaining cases exhibited no appreciable mandibular growth or forward movement of the molar.

In order to determine whether any correlation existed between the change in relationship of the molars to the line S-Gn and the changes observed in the mandible, a cross grouping was made and is shown in Table I.

The following additional measurements were made but yielded no significant changes:

1. Angular change occlusal plane to mandibular border.
2. Months of active treatment.
3. Angle of Frankfort plane to mandibular border at the beginning of treatment.
4. Angular change of Frankfort plane to mandibular border during treatment.

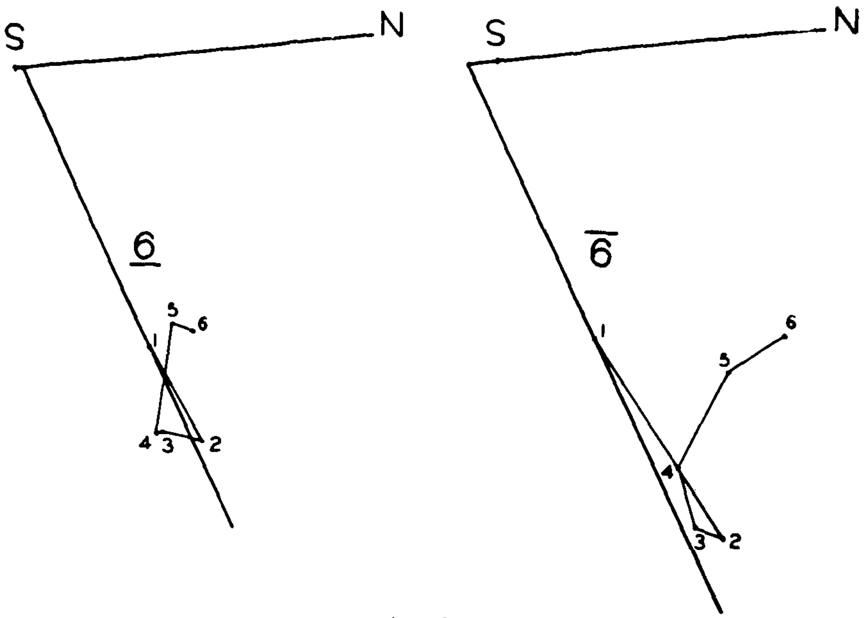

FIG. 3c

Age	N-S-6	N-S-$\overline{6}$	N-S-Gn
14.1-23	69.5	76.2	70.5
14-7-3	69.0	74.8	70.2
15-1-4	71.1	76.7	71.8
15-5-6	70.9	76.3	71.5
16-9-25	71.0	75.9	72.6
18-7-6	70.8	74.9	72.4

DISCUSSION

In a study employing longitudinal measurements the factor of human error has greater significance than in a cross sectional study where the results are expressed in terms of means. This is particularly true in a measurement of angles on consecutive tracings of roentgenograms of the same individual. Here the slightest difference in head position may change the position of an anatomical landmark. The raw data obtained from consecutive tracings must be interpreted in the light of evidence derived from various superpositionings of the tracings. In this study a temporary angular variation of 2.0° was considered to be a constant provided the variation did not show a trend in either direction. When a trend appeared, however, it was considered to be significant if only of 1.0°.

Of the seventeen cases in which $\underline{6}$ remained constant and $\overline{6}$ was found to be forward of its original position, eleven showed considerable mandibular growth and slight or no forward movement of the tooth within the bone. Seven of this first group of eleven showed a constant angle N-S-Gn. Typical behavior is shown in Fig. 3a. Four cases of this first group of eleven showed an increase of the angle N-S-Gn and a typical case of this category is shown in Fig. 3b. Both of these cases show, as do most of the cases studied, an initial posterior tipping of the upper molar, but this tooth regains its original axial inclination after engaging in the proper inclined plane relation. It must be realized that when the angle N-S-Gn increases, the

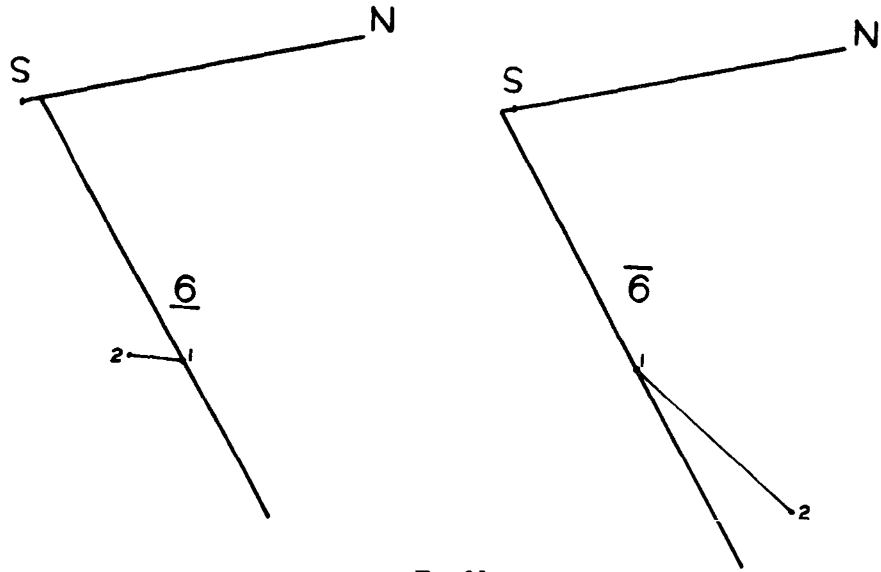

FIG. 3d

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
12-5-10	68.9	74.8	71.8
15-3-27	71.2	74.3	73.1

molar must also be further back if it retains its original relation to this line. The three cases of the second group in the first column of Table I in which mandibular growth and forward movement of the molar were of equal amounts presented pictures essentially the same as those seen in the first group. Two of the three cases showed the angle N-S-Gn to open while it remained constant in one. In the third group of column one there is one case showing slight mandibular growth and considerable forward movement of the lower molar within the mandible. The end results give the same picture as seen in the first two groups, but the paths followed by the molars in this case are rather interesting. Fig. 3c illustrates these paths. It is noted that this case was under active treatment for thirty-one months and that there was an 8.0° change in the occlusal plane. This was a greater than average change. In two cases in which it was shown that the change in molar relationship was brought about entirely by forward movement of the lower molar in space without appreciable growth or change in its relation to the mandible, a problem was presented that was difficult to explain. Figure 3d shows the molar paths in one of these cases. The outstanding change in this case is the 11.0° tipping of the occlusal plane. Since Brodie, Downs, Goldstein, and Myer in 1938[14] showed that the change in occlusal plane during treatment tends to return toward its original level after treatment, it is conceivable that a subsequent roentgenogram would show this tendency and present a pattern similar to the preceding ones.

In the second type of molar movement $\underline{6}$ is shown to go posteriorly while $\overline{6}$ goes anteriorly in relation to the line S-Gn. This is shown in Fig. 4 and is the case in which mandibular growth and forward movement of the molar is negligible. Here again there is a shifting of the occlusal plane of 9.3°. The other case of this type presented relatively the same picture, but the growth changes are quite marked. It is significant that in both of these cases the angle N-S-Gn had remained constant.

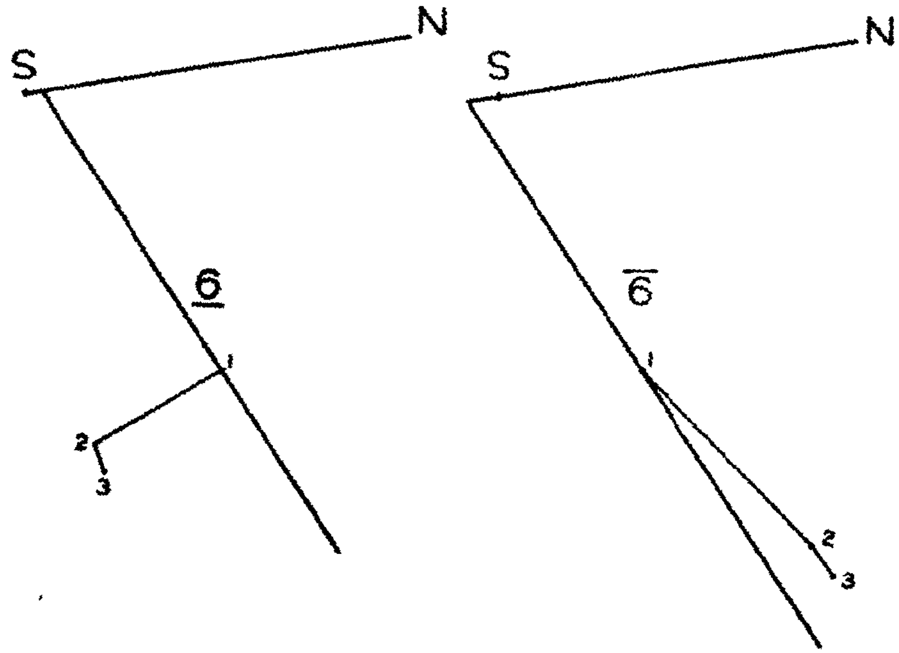

FIG. 4

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
12-9-10	63.4	72.0	66.8
14-4-15	66.0	70 8	66.5
15-3-5	66.0	70 8	66.8

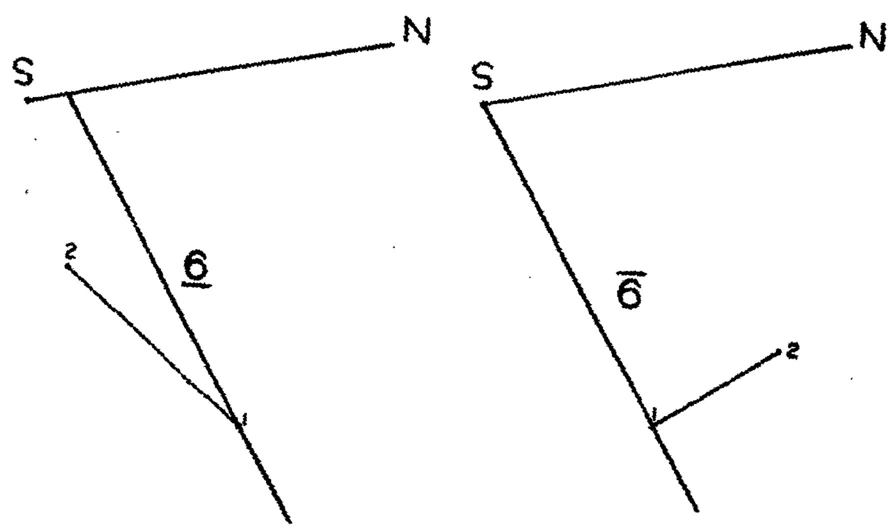

FIG. 5

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
20-11-3	66.1	71.8	71.8
24-8-20	68.7	71.1	73.7

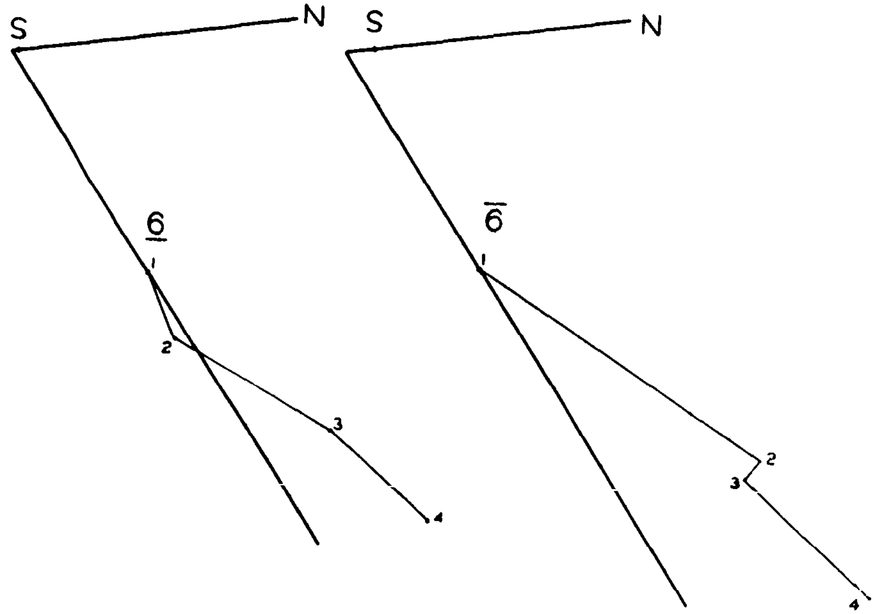

FIG. 6

Age	N-S-$\underline{6}$	N-S-$\overline{6}$	N-S-Gn
11-7-5	65.9	70.8	64.5
13-3-19	66.5	67.8	65.1
15-3-27	66.0	69.7	66.9
16-10-14	65.8	69.3	67.2

In the third type of molar change $\overline{6}$ is apparently constant to S-Gn and $\underline{6}$ has been moved posteriorly. The first of the two cases in this category showed a decrease of the angle N-S-Gn and is the only case out of the twenty-three studied which showed such a decrease. This can easily be accounted for when the tracings are superposed and the large amount of growth in the anterior direction is observed. The other case of this type is one in which growth was negligible, and the angle N-S-Gn had increased. However, there was a shifting of the occlusal plane of 10.6°. This case is diagrammed in Fig. 5. If vertical growth had been the equivalent of anterior growth, in the former of the two cases, the angle N-S-Gn would have remained constant. Under these circumstances the pattern obtained would have been similar to that seen in the first type (Column 1 — Table I). In the second case, however, the angle N-S-Gn increased due to a tipping of the occlusal plane. Had the angle N-S-Gn remained constant here, the pattern would have been more exaggerated. It would have shown a greater posterior tipping of the upper molar. This can be seen by superposing of the tracings. The behavior of this case can be accounted for by the fact that the patient was beyond the age where significant growth is expected.

The remaining two cases show a fourth type of molar change in which both molars are in a more forward position. Both cases showed an increase of the angle N-S-Gn, but one showed a negligible amount of growth and a negligible amount of forward movement of the molar in relation to the mandible. This case does not show a marked improvement of the molar relationship and the clinical result is poor. The other case, which is diagrammed in Fig. 6, showed good growth as well as an equivalent amount of forward positioning of the lower molar. Growth apparently accounts for the mesial relation of both molars to the line S-Gn.

The two most constant observations on the clinically successful cases were (1) a tendency for the lower molar to be repositioned in a more forward relationship to the line S-Gn without significant change in its relation to the mandible, and (2) a tendency for the upper first molar to show an initial posterior relation to the line S-Gn. Subsequent records indicate a tendency for the upper molar to regain its original relation with the line S-Gn without disturbance of the normal intermolar relation obtained by treatment.

CONCLUSIONS

1. In untreated cases, the upper and lower first permanent molars bear a definite and constant angular relationship to the line S-Gn in the individual.
2. The angle N-S-Gn increases in approximately one-half of the treated cases. In the other half it remains constant.
3. The angular relationship between the first permanent molars and the line S-Gn is altered in the treatment of Class II Division 1 malocclusions.
4. In the majority of cases the lower first permanent molar shows a forward positioning in relation to the line S-Gn.
5. The majority of cases show a constant relation of the upper first permanent molar to the line S-Gn. There is an initial posterior tipping of the upper first permanent molar but the axial inclination of the molar is regained eventually. During the period of posterior tipping, the face is growing downward and forward.
6. Mandibular growth accounts for the major amount of change in molar relationship.
7. Treatment accompanied by little or no growth appears to cause a change in the facial pattern as observed by the tipping of the occlusal plane.

TABLE I

	6—Const. 6—For.	6—Back. 6—For.	6—Back. 6—Const.	6—For. 6—For.
Mand. Gro. Great For. Molar Move. Sl. or None	11	1	1	
Mand. Gro. Equal to For. Molar Move.	3			1
Mand. Gro. Sl. or None For. Molar Move. Great	1			
Mand. Gro. Neg. For. Molar Move. Neg.	2	1	1	1

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703 WEST AVENUE

EIGHTEEN YEARS OF RESEARCH AT ILLINOIS

ALLAN G. BRODIE

(Cont. from p. 44)

As you can see our fears were justified. The successfully treated Class II malocclusion may result from a number of different phenomena and apparently, in this sample at least, the distal movement of maxillary molars occurs less frequently than almost any other movement.

In 1936 we had seen the results of Oppenheim's head-cap treatment in Vienna and upon our return had tried it on some of our clinical cases, but only in a half-hearted manner. When he came to this coutry, however, interest in this method of treatment revived and his visit to the department in 1945 kindled considerable interest in it. Dr. Myer undertook the treatment of a number of cases with this method and took very careful records in order to determine exactly what changes occurred under this method of treatment. By 1946 we had collected enough material to make preliminary appraisal possible. Dr. Walter Epstein undertook this appraisal and his thesis will be the next one to be incorporated into this review of eighteen years of research at Illinois.