Various conditions of the temporomandibular joint as revealed by cephalometric laminagraphy

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One of the oldest problems of bone morphology, is that of determining the effects of pressure on bone formation. Among the early invesigations in this field were those of Heuter (1862) and Volkman (1862). Their studies on the growing area of the epiphyseal plate led to the belief that pressure inhibited bone growth while release of pressure favored it. Such a concept was applied to all areas of growing bone and was rarely questioned until Julius Wolff (1892) postulated the law of functional adaptation. This law resulted from the mathematical analysis of the trabecular arrangement of the spongiosa of bone in terms of its function. Geometrically arranged trajectory lines were demonstrated and were shown to be consistent with the stresses set up during function. This observation implied that bone was formed as a result of function and it seemingly contradicted previously held ideas.

Actually there were no disagreements in these concepts. Both were true but required interpretation before clinical applications could be made. However, the theory of Wolff lent itself to the conception that the overall form of a bone was determined almost solely by its function.

With such far reaching implications it was not long before Wolff's law found its way into dental literature. By 1901 Tomes and Dolomore had applied it to the temporomandibular joint. In describing growth and treatment changes in this area they held that joint form was determined by function of the teeth. They further postulated a migration of the glenoid fossa within the temporal bone as a result of changes in the occlusion.

This belief, with some reservations and modifications, has been supported more recently by Reisner ('38), who claimed that morphological variations of the temporormandibular joint would be found to be consistent with different types of malocclusion of the teeth. From histologic studies of monkeys, Breitner ('41) described changes in the condyle following changes in mandibular position. No controls were employed, however.

This functional concept was widely held but not accepted by all. Opposed to it was Todd ('39), who denied that function of the teeth had anything to do with the form of the temporomandibular joint. Basing his arguments on phylogenetic grounds he held that temporomandibular joint form was determined by factors quite apart from occlusion. He believed that it was related to the attainment of upright posture and stated that the temporomandibular joint played a passive part in mastication.

Todd's idea seemed to be extremely radical but he was soon to have his contentions supported by Brodie's observations on the growth of the head ('41). Since Brodie found striking orderliness in the development of the

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skull, he felt that the jaw articulation did not behave unlike the structures found in other parts of the skull and therefore was determined primarily by hereditary factors with mechanical or functional factors playing a secondary role. Brodie's ideas were even more convincing when alizarination of growing monkeys (Schour and Massler, '40) demonstrated that late growth changes seemed to result more from the activity of specific sites than from a general growth process. These conflicting opinions pointed to the need for a study of morphological variation of the temporomandibular articulation because longitudinal study had demonstrated wide ranges in the morphological variation of all other parts of the skull.

The kinetics of jaw function have further contributed to the confusion. Bonwill (1887) was one of the first to attempt a mechanical interpretation of the biological phenomenon of jaw function. Neglecting many of the physiological and anatomical facts even of his day, he formulated what might be called the articulator concept of function of the teeth. This was a prosthetic approach and its main purpose was to aid in the stabilization of artificial dentures. The theory held: (1) that during mastication there is a bearing point at the condyle and balancing points on each of the two sides of the dental arches; (2) that both sides of the normal arch are in contact simultaneously during function: (3) that the opening and closing movements of the mandible are over the same paths. These views are those most widely held by the dental profession and they have exercised a profound influence on its thinking.

Mechanical articulators have been designed to meet the hypothetical demands set up by Bonwill and have been employed for the arranging of artificial teeth. Undoubtedly this has led to advances in the construction of artificial dentures but there has developed the conviction that the natural denture behaves in the same manner. However, such views have not gone unchallenged by investigators.

As early as 1889 Luce demonstrated photographically that the condyle could, in normal cases, move anterior to the summit of the articular eminence in mouth opening without becoming dislocated. Several investigations were made in the next decade to determine the function of the external pterygoid muscle in the opening movement. Constant ('00), Chissin ('09) and Prentiss ('18) were among those who stressed the function of the external pterygoid in mouth opening as opposed to the widely held idea that the hyoid group was solely responsible.

Hildebrand ('31), by means of cinematography, x-ray photography, kymography and fluoroscopy studied jaw function in three planes of space, both with and without food in the mouth. He confirmed the finding that there was a preponderance of forward movement of the condyle in the beginning stages of the opening movement. Among his other conclusions were: (1) that the paths of movement of the mandible in the final phases of closing were dictated by the teeth; (2) that movement of the mandible in opening and closing did not necessarily occur over the same path although it might; (3) that in the final closing phases of the chewing movement unilateral function could be demonstrated in the temporomandibular joints. For the most part, Hildebrand limited his observations to the movements of the mandible and did not concern himself with the position of the condyle in the fossa at the beginning or at the completion of movement.

The most recent attack on the problem of mandibular position was that

Fig 1. Cephalometric Roentgenogram — Teeth, mandible and mid-line structures can be viewed but area of the joint is not visible.

made by Thompson and Brodie ('42) on the growth behavior of the mandible and Thompson ('46) on the physiologic rest position of the mandible and its significance. These observations were made by means of cephalometric roentgenography. The major points of this concept are that the mandible, as a part of the postural system of the head, has a resting position that is determined by musculature and that this position is the same regardless of the presence or absence of teeth. Thompson described a space between the teeth with the mandible at rest which he called freeway space. Interocclusal dimension at the molar has been substituted for this term because it designates the point of measurement. All movements were held to begin and end at the rest position since it was determined by the natural resting length of the musculature. A typical mandible was described as moving in an upward and forward path of closure from the resting position with a point or an axis of rotation somewhere near the center of the condyle. When malposed teeth interfered with the normal closure, a deflection of the mandible could occur in any direction dictated by the interference.

In the course of clinical application of this concept, many cases were observed to have an atypical path of closure even in the absence of deflecting agents such as malposed teeth. This observation, together with those previously mentioned, suggested that a study of the area of the temporomandibular joint might reveal certain information that would be important to orthodontic and other dental fields.

Methodology

Cephalometric headplates have yielded excellent information on the growth of the face and the movements of the

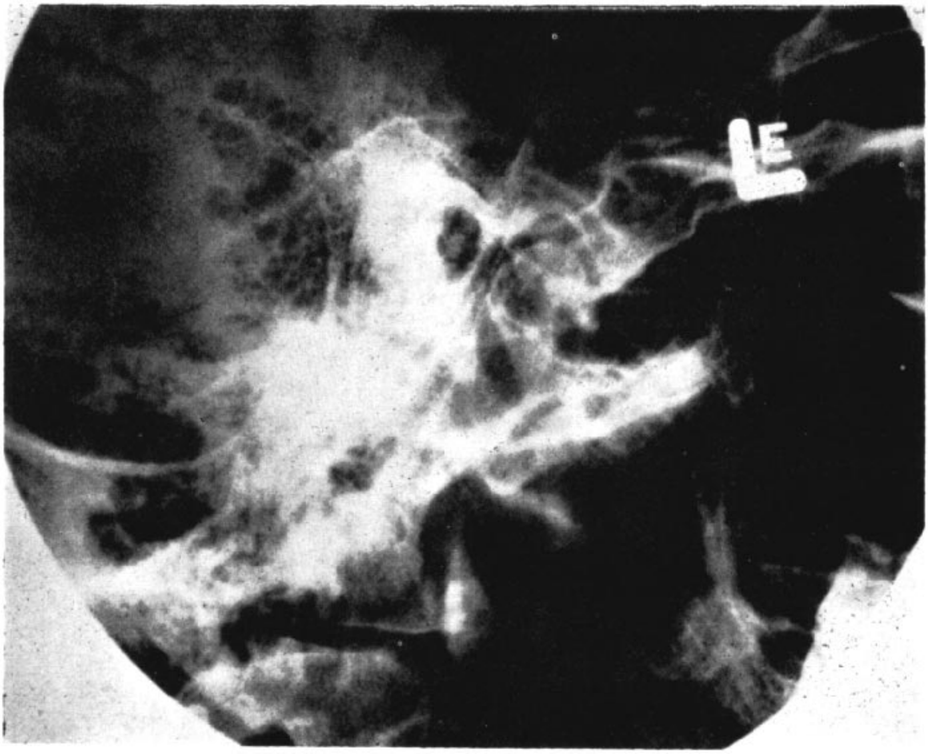

Fig. 2. Lateral temporomandibular x-ray — Reveals joint structures but introduces distortion, lack of orientation planes and area does not include teeth and mandible.

mandible. In such radiographs the teeth are discernible and the facial structures can be viewed in detail but the area of the condyle is not visible due to the interference of the petrous elements of the temporal bones. (Fig. 1) In an effort to overcome this limitation of the direct lateral exposures, various angular techniques have been devised to avoid the superimposed structures. The details of these techniques will not be dealt with here. It is sufficient to point out that they introduced distortion, uncontrolled enlargement and lack of orientation. Films made in such a manner were found to be unreliable for purposes of controlled study. Figure 2 is an x-ray of the angular exposure technique of the same patient as that seen in Fig. 1. The posterior slope of the eminence and the condyle in its fossa are evident. It will be noted, however, that the teeth are out of the field so that only the area of the joint itself can be seen.

Recognizing the shortcomings of available methods, Brader ('48) applied the principles of roentgenographic cephalometry to laminagraphy. Briefly, the method of laminagraphy permits the visualization of structures lying in a prescribed plane even though they may be partially or wholly covered by denser structure. By using correctional scales and a head positioning device, Brader proved the method sufficiently accurate for purposes of investigation. As an outgrowth of this original work, Ricketts ('50) applied the cephalometric laminagraphic technique to the temporomandibular joint. Information on this technique has appeared in the dental literature and will not be dealt with here.

Figure 3 is a laminagraph of a plane

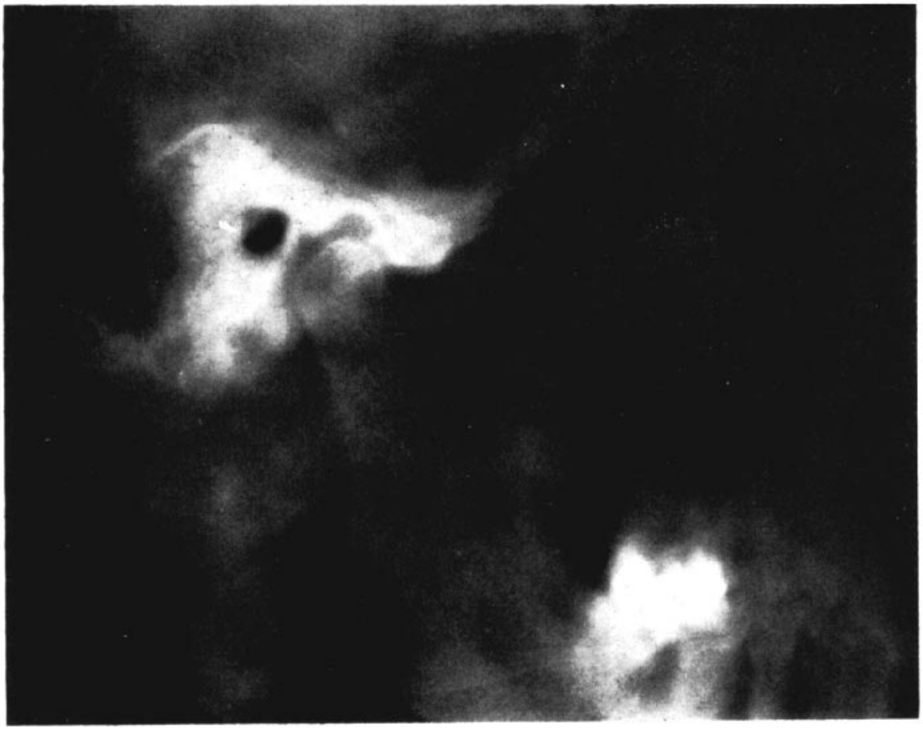

Fig. 3. Cephalometric laminagram — True lateral view with orienting planes of reference, teeth and joint visible on one film.

through the temporomandibular joint of the patient seen in Figs. 1 and 2. Figure 4 is a tracing of Fig. 3. The following anatomical points and landmarks can be observed. (Z) zygomatiofrontal suture; (O) point orbitale; (ZO) rim of the orbit; the jugal process or key ridge; the articular eminence: the glenoid fossa and post glenoid process; (P) the external auditory meatus with the point porion; (M) the mastoid process; the ramus of the mandible with condyloid and coronoid processes, sigmoid notch and alveolar canal; (T) the centrobuccal cusp of the lower first molar; (C) the tip of the lower canine. For purposes of study, the following lines are constructed: (RR') line through the long axis of the neck of the condyle; (HH') a perpendicular to the Frankfort horizontal plane erected through the summit of the eminence.

The objectives sought by the method were threefold, viz: (1) to provide a true lateral exposure of the joint and one free of distortion; (2) to obtain successive films that would be strictly comparable by the use of orienting devices; (3) to expose a field large enough to include the joint, the mandible and the teeth.

Material

The material studied consisted of cepahlometric laminagraphs of both joints of 50 patients taken (a) at rest position, (b) with the teeth in occlusion, and (c in the wide open mouth position. The first group consisted of 62 percent normal or acceptable occlusions, 25 percent Class I malocclusions, 8 percent subdivision Class II malocclusions and 4 percent subdivision Class III malocclusions. The averages age of the sample was twenty-one years. A second group consisted of 50 patients

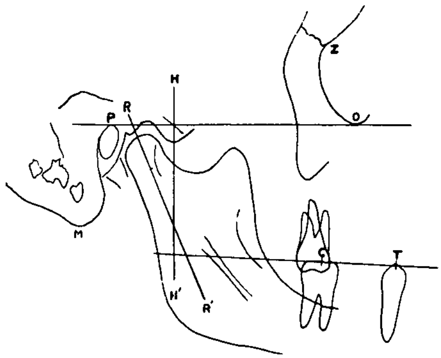

Fig. 4. Tracing of Fig. 3 — Points, landmarks and orienting planes are indicated.

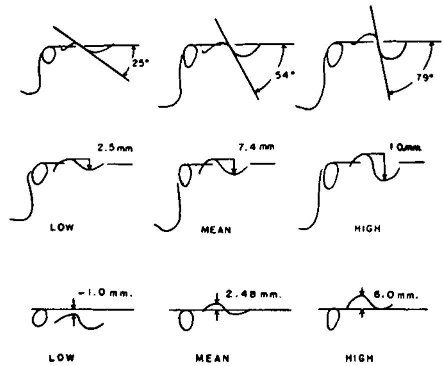

Fig. 5. Variation characteristic of the normal morphology — A. Angle of the eminence, B. Height of eminence, C. Relation of the fossa to Frankfort Plane.

exhibiting unquestionable Class II malocclusions. Forty-eight percent of this group were Division 1, 38 percent were Division 2 and 14 percent could not be classified as to division. The average of the Class II group was fourteen years.

FINDINGS

Morphology

The first observation in the study was of the comparative size of the condyle to the fossa with which it was associated. A very simple rating scale was established and the condyles were classified as very small, small, average, large, or very large, in relation to the fossae circumference. The 200 joints analyzed yielded an almost perfect curve of distribution. Exactly one half of the condyles were found to be of average size; 45 were small and 45 were large; 7 were extremely large and 3 were extremely small. These findings would seem to indicate that the articular elements of the temporal bone and those of the mandible are independent variables and that, under natural circumstances, there is not the functional adaptation of one to the other that has been so frequently claimed. A slight difference was found between the two samples in that the condyles in the younger ages tended to be smaller than adult condyles in relation to their fossae. This was thought to be due to the difference in the mean age of the groups.

The morphologic variation of the articular eminence was determined by measuring the angle formed by the articulating surface and the Frankfort plane. The low of the range was found to be 25 degrees, the average was 54 degrees and the extreme high was 79 degrees. Thus, the total range of variation was 54 degrees with a standard deviation of 10 degrees. (Fig. 5)

The height of the eminence, measured from its summit to the roof of the fossa on a perpendicular to Frankfort plane, exhibited a range from 2.5 mm to 11 mm with a mean of 7.4 mm. In neither of these measurements could a difference be established between the groups studied.

At the suggestion of Dr. Wendell Wylie, the relation of the fossa to the Frankfort plane was measured. It was found that the fossa ranged in position from slightly below the Frankfort plane to 6 mm above it. The mean Frankfort plane almost bisected the eminence and the fossa. A standard deviation of 1.3 mm seemed to validate Wylie's method of locating the position of the glenoid fossa superoinferiorly. ('47). (Fig. 5)

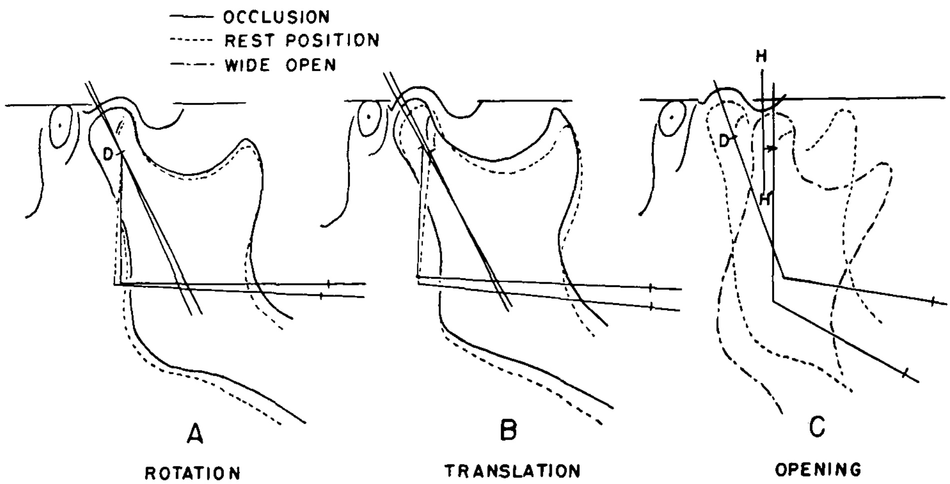

Fig. 6. A. Represents rotation of the condyle around point "D". Characteristic of about 85% of the control cases from rest to closure. B. Rotation plus translation, characteristic of about 15% of the control. C. Mean wide open position with "D" measured from line HH'.

Function

To study the behavior of the condyle in wide mouth opening the following method was used: a perpendicular to the Frankfort plane was drawn through the lowest point on the articular eminence (Fig. 6 C). This line (HH') was employed as a base line of measurement. A point just below the center of the condyle on the line RR' (Fig. 4) was marked on the tracing of the jaw in resting position and was transferred to subsequent tracings of superpositioning.

The point of rotation in the head of the condyle in the closing movement from rest position, described by Thompson ('46), was confirmed. This is a point slightly below the center of the condyle at about the level of insertion of the external pterygoid muscle and the attachment of the lateral ligament. The behavior of this point was uniform enough to warrant its use in evaluating the function of most cases. A typical case showing a preponderance of rotation around point D is demonstrated in Fig. 6A. This behavior was characteristic of about 85 percent of the control group. In 15 percent of the control cases this point moved as much as 2 mm from rest position to closure. An example of a case which exhibited a combination of rotation and translation is seen in Fig. 6 B.

The findings in the Class II group were significantly different. Approximately one third of the Class II cases were found to be similar in behavior to the control represented in Fig. 6 A. Another third resembled the small portion of the control represented in Fig. 6 B. The remainder of the Class II cases exhibited greater translatory

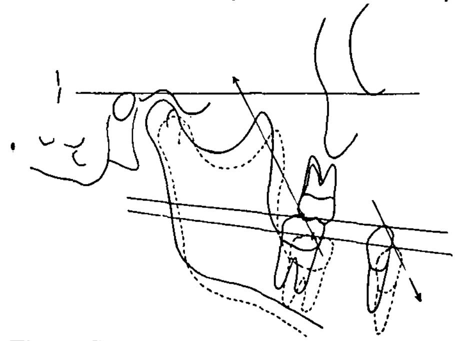

Fig. 7. Characteristic behavior in movement from rest to occlusion in about 35 to 40% of Class II cases. Note condylar and mandibular position downward and forward.

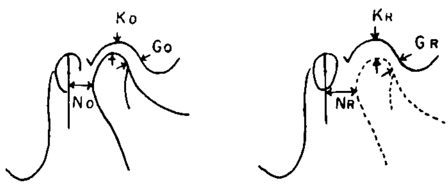

Fig. 8. Method employed in measuring position of the condyle in relation to the eminence, the fossa, and the external auditory meatus. Gr, Distance from condyle to eminence at rest; Go, same measurement in occlusion; Kr, distance from condyle to top of fossa at rest; Ko, same measurement in occlusion; Nr, measurement from line through center of EAM to posterior surface of condyle at rest; No, same measurement in Occlusion.

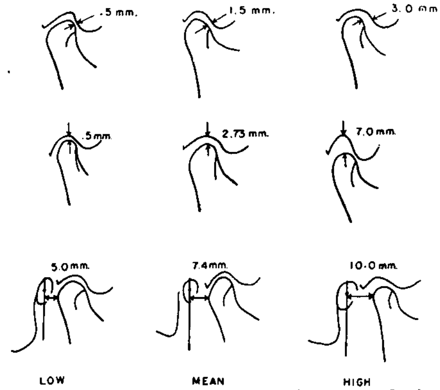

Fig. 9. Range of condyle-fossae relationships in control group of cases at physiologic rest position of the mandible. Top row — condylar-eminence dimensions; Middle row—supra-condylar dimension; Bottom row—condylar-meatal dimension. Occlusal relations are even less variable.

movement than any cases found in the control group. This movement ranged from 2.5 to 7 mm. A case exhibiting this behavior is illustrated in Fig. 7.

Resting Position of the Condyle

Since it had been determined that there was significant difference in movement from rest to closure in the samples, and particularly in the Class II group, the resting position of the condyle in the two groups was compared.

The method of determining position consisted of measuring the distance from the posterior slope of the eminence to the anterior border of the condyle, and from the tip of the condyle to the roof of the fossa. In addition, a perpendicular to the Frankfort plane was dropped through the center of the external auditory meatus and a measurement was taken from that line to the posterior border of the condyle. The same distances were measured at rest and in occlusion in both groups (Fig. 8).

It was noted that some condyles closely approximated the eminence, while others were appreciably distant from it. (Fig. 9) Some of the condyles were deeply seated in the fossa, while others seemed to hang loosely in it. Variation in the rest position of the condyle varied from 5 to 10 mm anterior to the center of the external auditory meatus. Since in the control none of these condyles moved more than 2 mm from rest position, the measurements in the occlusal position would differ very little.

A comparison of the two samples revealed that the Class II cases exhibiting wide movement from rest to closure had a resting position of the condyle that was downward and forward compared to that of the control. When the teeth were clenched, however, the condyle was found in a position that was almost identical to that of the control.

The differences in condylar position between the two groups can be observed in the graph in Fig. 10. In the control, the measurement from the roof of the fossa to the tip of the condyle with the teeth in occlusion, reveals the distribution seen on the light solid line. The light dotted line shows the variation of the Class II cases in occlusion. These two lines are practically identical. The heavy solid line shows the distribution of the control cases at rest. This curve is deflected slightly as would be expected from the findings on movement in the control series. The heavy dotted

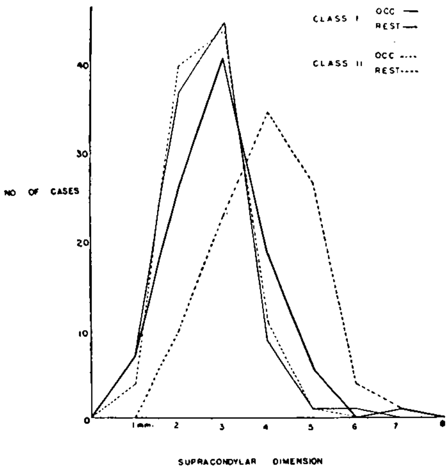

Fig. 10. Distribution characteristic of Class I and Class II rest and occlusal relations of condyle. Note heavy dotted curve indicating rest for the Class II skews significantly from the others.

line shows the distribution of the Class II cases at rest. Note that the form of this curve is different from the other three. Since the curve is skewed away from the line for the control group, there exists greater difference in the condylar position at rest than in occlusion, between the two groups.

The above findings brought under question our previous concepts of the resting position of the mandible. Those concepts had been based on evidence derived from cephalometric roentgenology which did not permit scrutiny of the glenoid fossa. It had been assumed that the resting position of the mandible would find the condyle in an upward and forward position in the fossa and that upward and backward movement from that position during jaw closure indicated an abnormal posterior and superior thrusting of the condyle. Our findings demonstrated that in a majority of those cases which exhibited a wide range of movement from rest position to closure, the condyle assumed the position characteristic of the control group when the teeth were brought into occlusion. This would indicate that the resting position in such cases was one which found the condyle downward and forward from the typical position.

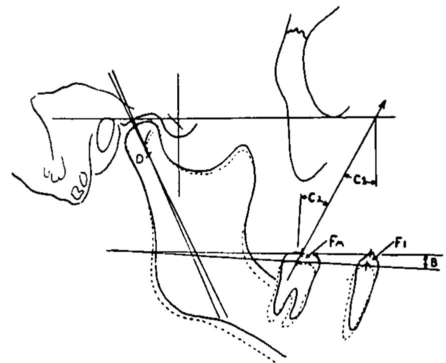

Fig. 11. Methodology for studying denture relationship and function from rest to occlusion. Cl — path of closure; Fm — interocclusal dimension at the molar; B — angle of divergence of the occlusal plane.

Tooth Relationship

In order to establish an occlusal plane for the lower denture (Fig. 11), the centrobuccal cusp of the mandibular first molar and the tip of the mandibular canine were traced and connected by a straight line. In order to study the changes in mandibular position the tracings were superposed on cranial planes and a line drawn through the centro-buccal cusp of the first molar at the rest position and with the teeth in occlusion indicated the path of closure. This could be measured as an angle to the Frankfort plane or to the occlusal plane. The distance between the molar points was measured and taken as the interocclusal dimension of the molar at rest. The angle formed by the intersection of the occlusal planes at rest and in occlusion was taken as a measure of rotation of the mandible.

A study of the path of closure revealed that the mandible did not necessarily travel upward and forward. When measured from a perpendicular

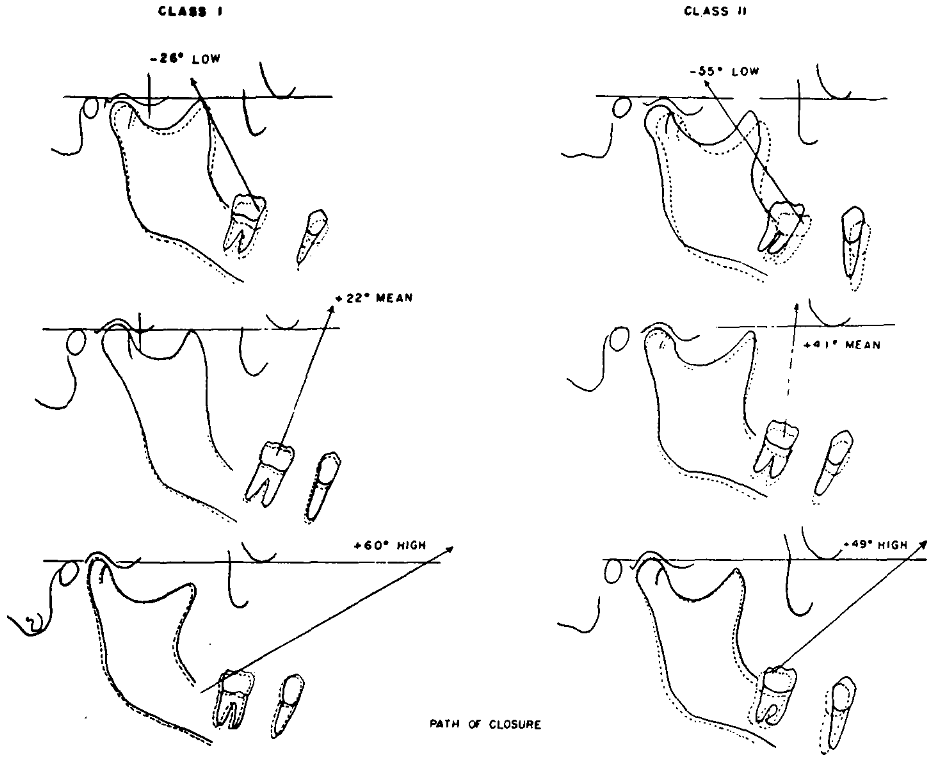

Fig. 12. Path of closure variation in the control (left) and Class II (right).

to the Frankfort plane, the range in this movement varied from an upward and forward direction of + 60 degrees to an upward and backward direction —26 degrees. The mean value was found to be +22 degrees. The range of the sample was therefore almost 90 degrees. In the Class II group the range and its mean shifted about 15 degrees in a backward direction (Fig. 12).

The difference observed in the interocclusal dimension with the mandible at rest position and in occlusion was striking. The control group revealed a mean distance of 1.8 mm at the first molar with a variation of .5 to 4.5 mm (Fig. 13). The Class II group exhibited significantly higher figures, the mean being twice that of the control (3.5 mm). The high figure for Class II was determined to be 7.5 mm.

Some cases with forward rest position of the condyle were associated with a direct downward and forward position of the mandible similar to a position seen in protrusive movement. In others, an identical condylar position was combined with a rotation of the mandible, with the chin point dropping downward as in opening. The angle made by the crossing of the occlusal planes at rest and in occlusion was taken as a measure of this rotation. It was found that this angle was a more reliable measure for comparison than was the interocclusal dimension because the difference was more significant statistically. It was found that the Class II cases had greater rotation with a mean of 2.75 degrees (range 0 - 7) than the control with a mean of 1.6 degrees (range 0 - 4.5).

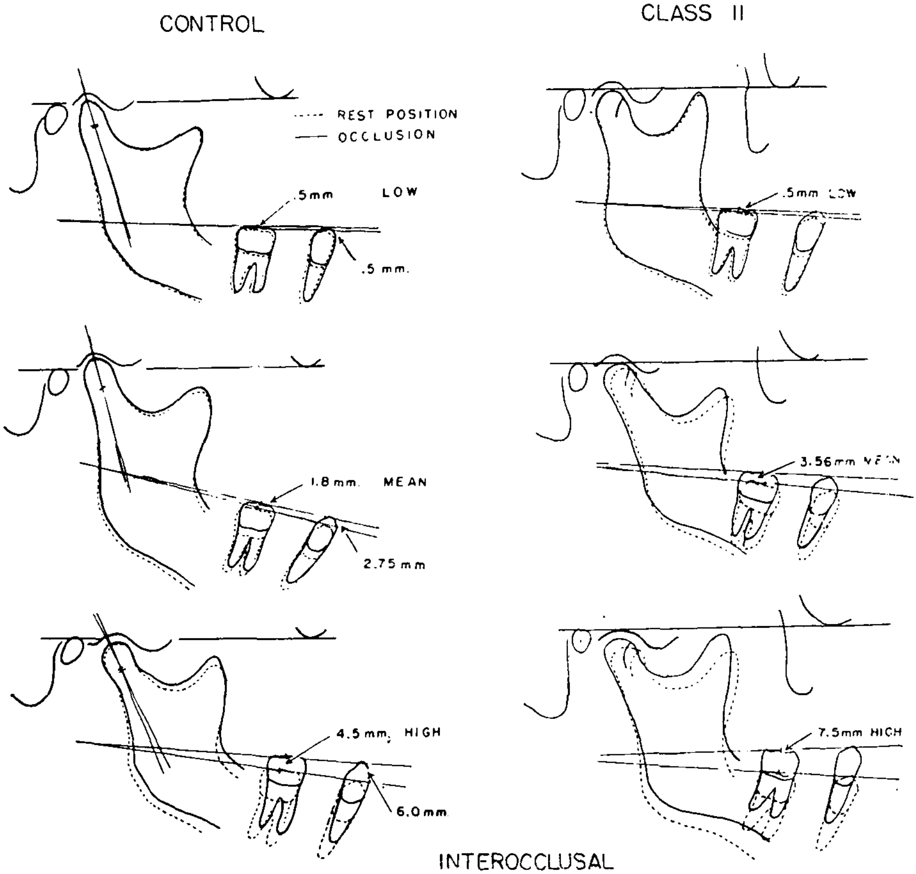

Fig. 13. Interocclusal dimension in the control (left) and Class II (right).

The means, standard deviations and extremes of measurements pertinent to laminagraphic analysis of the joint are given in Fig. 14. These are the figures for the control group and are accepted as reliable for comparison of an individual case. Condyle-fossa relationships are under one heading and denture relationships under another.

Figure 15 A represents a Class II Div. 2 case which revealed a typical Class II mandible and a retruded relation of the upper incisors at the beginning of treatment. Treatment included the extraction of upper first bicuspids (Fig. 15 B). The resting position of the mandible prior to treatment resulted in a wide interocclusal dimension. The path of closure was within normal limits, although a translation at the head of the condyle of approximately 4 mm occurred (Fig. 15 C). In closing from rest, the condyle moved from a downward and forward position on the eminence to a position that was thought to be retruded. At the end of treatment, it was found that the space between the teeth had diminished markedly while the path of closure had remained unchanged (Fig. 15 D). However, the condyle had now assumed a position, both at rest and at full closure, that was typical of the position with the teeth in occlusion before treatment.

Figure 15 E is a tracing of the before and after laminagraphs superposed on

STANDARDS FOR LAMINAGRAPH ANALYSIS

CONDYLE-FOSSA RELATIONSHIP	MEANS	STANDARD DEVIATIONS	RANGES LOW	RANGES HIGH
MOVEMENT FROM REST TO CLOSURE	.5 MM.		0	2.0 MM
CONDYLAR-EMINENCE DIMENSION IN OCCLUSION	1.5 MM.	±.5 MM.	.5 MM	3.0 MM
SUPRACONDYLAR DIMENSION IN OCCLUSION	2.5 MM.	±1.0 MM	.5 MM	5.5 MM
CONDYLAR-MEATAL DIMENSION IN OCCLUSION	7.5 MM.	±1.5 MM.	5.0 MM	10.0 MM
DENTURE RELATIONSHIP				
CANT OF OCCLUSAL PLANE	7.5° (97.5°)	±5.5°	-6°	+16°
INTEROCCLUSAL DIMENSION AT FIRST MOLARS	2.0 MM.	±1.0 MM.	.5 MM	4.5 MM
ANGLE OF DIVERGENCE OF OCCLUSAL PLANE.	1.5°	±1.0°	0	4.5°
PATH OF CLOSURE	22° (112°)	±21°	-26°	+60°

Fig. 14. Data chart of a control group of 100 joints for comparing individual cases.

the cranial plane with the mandible at rest position. The tracings indicated that condylar position at rest had changed during treatment together with the mandibular relation. In the beginning, 6 mm interocclusal dimension at the molar was present and at the end of treatment the dimension had narrowed to 1.5 mm. The vertical height of the face at physiologic rest was less following treatment in spite of growth. The path of closure had gone from —2 to +9, which was within the normal limits. Only one half a millimeter of growth could be measured along a plane from the fossa to the zygomaticofrontal suture, but mandibular growth at the condyle was determined to be 6 mm during treatment (Fig. 15 F). Figure 16 shows the data for Case No. 12.

Figure 17 A and B shows a Class II Div. 1 case that was treated with cervical anchorage and a bite plate. Four bands were placed to rotate the upper incisors but the mandible was never touched. At the start, the position of the condyle at rest seemed to be slightly downward and forward with an upward and backward path of closure outside that of the control range (17 C). The condylar position in occlusion, at the posterior limit of the range, was suspected of being thrust distally. The condylar-meatal measurement in occlusion was 5.0 mm and the supracondylar measurement 1.5 mm, both of which were at the low extreme of the standard range (Fig. 14). At the end of treatment the condyle still moved upward and backward although not to so high a position (17 D) as before treatment. The interocclusal dimension was slightly diminished and the path of closure was not quite as far upward and backward, falling within normal limits, or within the range of our standard. Following treatment there was a 6.0 mm condylar-meatal distance and 2.5 mm supracondylar distance, indicating a slight change in occlusal relation of the condyle. In other words, those measurements noted to be outside the control range before treatment changed to measurements within the range by the time the case was retained.

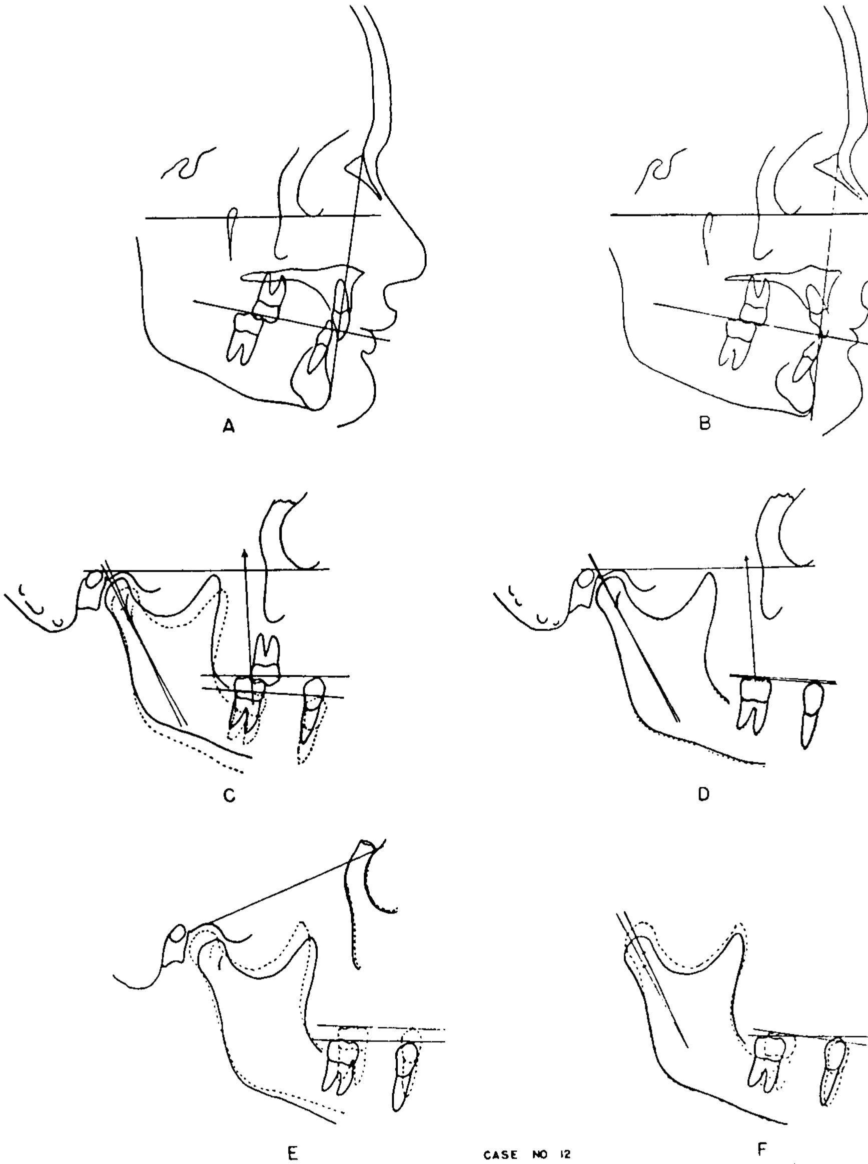

Fig. 15. Records of Case No. 12. A, Before treatment headplate tracings. B, After treatment headplate tracings. C, Laminagraph analysis before treatment. D, Laminagraph analysis after treatment. Note difference in interocclusal dimension. E, Before and after laminagraph tracings of rest position superimposed on fossa and zygomatico frontal suture and registered at the fossa. Note change in rest position of the condyle. F, Laminagraph tracings before and after superimposed on the angle of the mandible.

CHANGES DURING TREATMENT

CONDYLE-FOSSA RELATIONSHIP	BEFORE	AFTER	DIFFERENCE
MOVEMENT FROM REST TO CLOSURE	4.0	0	-4.0 MM.
SUPRA CONDYLAR DIMENSION IN OCCLUSION	2.5	2.5	0 MM.
SUPRA CONDYLAR DIMENSION AT REST	7.0	2.5	-5.0 MM.
DENTURE RELATIONSHIP			
INTEROCCLUSAL DIMENSION	6.0	1.5	-4.5 MM.
ANGLE OF DIVERGENCE	4.0	1.0	-3.0°
PATH OF CLOSURE	-2.0	-11.0	-9.0°
GROWTH ANALYSIS			
CRANIAL PLANE			.5 MM.
CONDYLAR PLANE			6.0 MM.
AGE	13-6	16-6	36 MONTHS

CASE NO. 12

Fig. 16. Data for Case No. 12.

Figure 17 E shows the before and after laminagraph tracings superimposed on the cranial plane and registered at the fossa. It also shows the before and after rest position of the mandible. The condyle moved slightly upward and backward at rest as 4 mm of growth had been enjoyed by the mandible during treatment (Fig. 17 F). The condyle had come forward about 1 mm in occlusion but had gone back at rest. There seemed to be a position somewhere between the beginning rest and occlusal positions that was correct for this case.

The data chart in Fig. 18 indicates the changes in this case. Interocclusal dimension had diminished 2 mm and the path of closure had come forward 26 degrees. Cranial growth was of about the same magnitude as mandibular growth, being 3½ and 4 mm respectively.

Discussion

The study indicated strongly that few generalizations that are usually held regarding the morphology of the temporomandibular joint are tenable. The individual parts of the joint, and particularly the condyle head and the temporal fossa, exhibited wide ranges of variation in form and size. Furthermore, there seemed to be little if any correlation between the extreme forms of these two parts. Thus, small condylar processes were found to be associated with relatively large fossae and large condyles with fossae that seemed too small to accommodate them. Marked variation was also found in such details as depth and location of the fossa, its relation to the Frankfort horizontal plane, and the slope of the articulating eminence. The same range of variation in these morphological details was observed in the control group and in the Class II malocclusions.

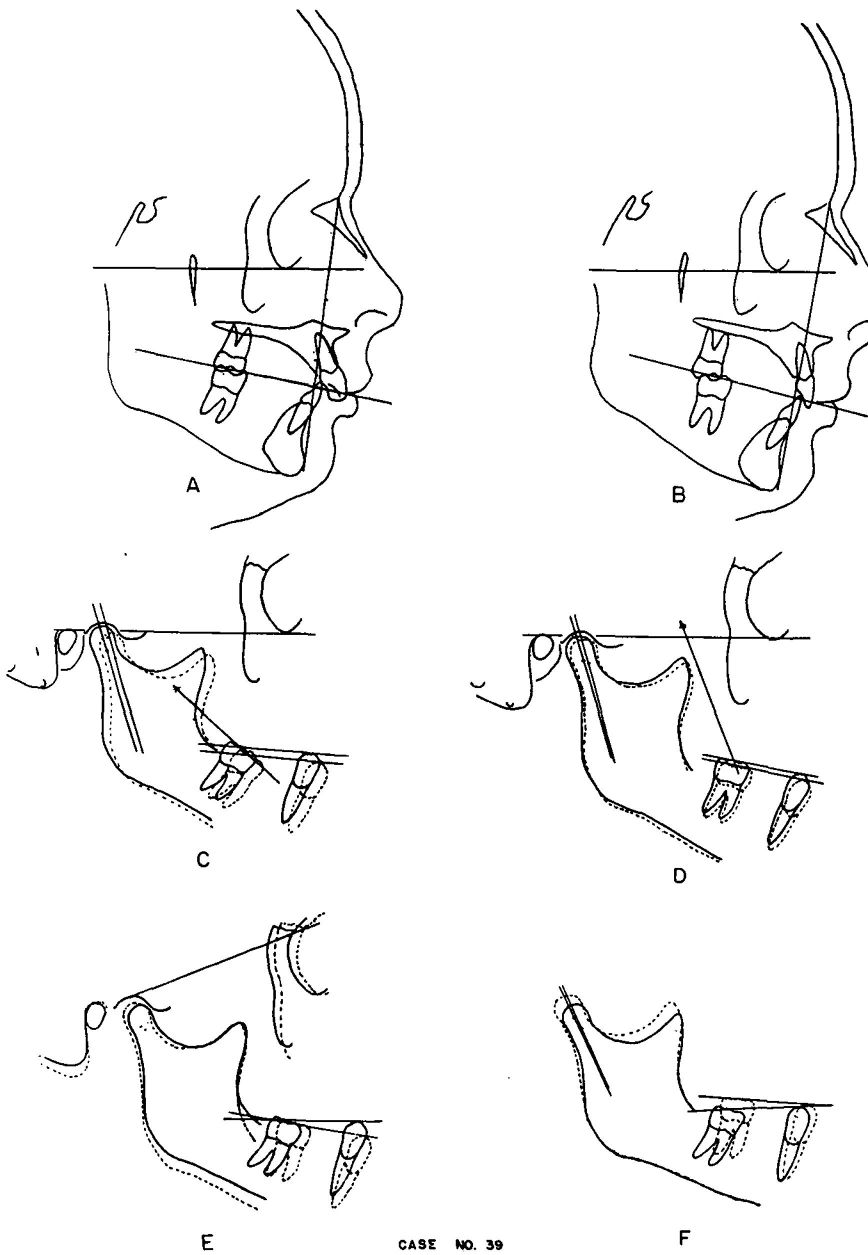

Fig. 17. Records of Case No. 39. A and B, before and after headplate tracings. C, Laminagraph analysis before treatment; note distal path of closure. D, Laminagraph analysis after treatment; path of closure within range of standard. Condyle had come forward in position of occlusion of the teeth. E, before and after laminagraph tracings superimposed on cranial plane. F, before and after laminagraph tracings superimposed on angle of mandible.

CHANGES DURING TREATMENT

CONDYLE-FOSSA RELATIONSHIP	BEFORE	AFTER	DIFFERENCE
MOVEMENT FROM REST TO CLOSURE	3.5	1.0	-2.5MM
SUPRA CONDYLAR DIMENSION IN OCCLUSION	1.0	2.0	+1.0MM
SUPRA CONDYLAR DIMENSION AT REST	4.0	2.0	-2.0MM
DENTURE RELATIONSHIP			
INTEROCCLUSAL DIMENSION	3.0	1.0	-2.0MM.
ANGLE OF DIVERGENCE	0	1.5	+1.5°
PATH OF CLOSURE	-48	-22	+26°
GROWTH ANALYSIS			
CRANIAL PLANE			3.5MM.
CONDYLAR PLANE			4.0MM.
AGE	10-5	11-8	15 MONTHS

CASE NO.39

Fig. 18. Data for Case No. 39.

The least variable condition proved to be the position of the condyle in the fossa when the teeth were clenched. Here the condyle was generally found in the fossa in the position usually portrayed as typical. This is understandable when it is realized that most techniques previously employed have required full occlusion of the teeth.

The only striking difference noted between the joints of the controls and those of the Class II sample was in their respective resting position. The controls tended to exhibit the typical relation, whereas two thirds of the condyles of the Class II group were found downward and forward on the eminence when in the relaxed position.

Our belief, based on the work of Thompson and Brodie, and Thompson, had been that there was little variation in the resting position of the condyle in either typical joints or those associated with Class II malocclusions. Translatory movements of the mandible from the resting to the clenched position as determined by the behavior of selected points on the mandible, were therefore assumed to be accompanied by an upward and backward thrusting of the condyle beyond the typical position. A technique that permitted scrutiny of the total condyle-fossa relation indicated that such translatory motion during closure more frequently started from a downward and forward point and ended at the typical position or relation.

The above findings led to the clarification of another clinical problem. It had been noted by a number of men that in the treatment of Class II Div. 2 malocclusion, when the upper incisors had been tipped labially in the initial stage of treatment, the lower jaw sometimes assumed a more forward position;

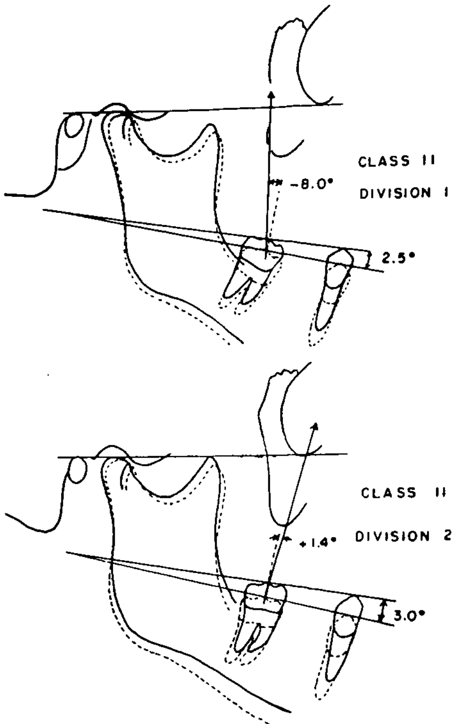

Fig. 19. Comparison of average path of closure and rotation of occlusal plane in Class II, Div. 1 and Class II, Div. 2 malocclusion. Note more distal direction of closure in Div. 1.

in some cases moving into a Class I relation. The investigations on the resting position of the mandible explained this behavior on the basis of the removal of an occlusal interference which permitted the mandible to assume its normal position in function as well as at rest. However, the repositioning of the mandible did not always follow the labial movement of the maxillary incisors.

When the Class II sample was divided into its two division and each was studied separately, it was found that the Class II Div. 1 cases exhibited, on the average, more posterior closing movement than did the Class II Div. 2 cases, in spite of the fact that the latter presented wider interocclusal dimensions. (Fig. 19)

One more observation should be noted in the discussion, viz, the changes in the condyle-fossa relationship after the treatment of Class II malocclusions. A number of these cases have been studied in which the generally accepted methods of treatment with the edgewise arch have been employed. Almost without exception, the condyle was found to be in a typical position, both at rest and at full closure, following treatment.

These findings would seem to call for a slight modification of our concept of the stability of the resting position of the mandible. Although we are still firmly of the opinion that the resting position represents an equilibrium of various forces, muscular and gravitational, and is hence extremely reliable under stable conditions, we can no longer accept it as unchangeable.

The maintenance of the position of the mandible is a function of the proprioceptive system, serving posture, occlusion, speech, deglutition and respiration, to mention only a few of the demands made upon it. So long as these functions and the parts that serve them remain relatively unchanged, the resting position of the mandible will remain unchanged. But with a marked change in any of these factors one can logically postulate changes in the state of equilibrium, followed by changes leading to a new stable position. This has been repeatedly shown in the field of orthopedics in cases which have suffered the loss of parts or of function and in which the neuromuscular and skeletal systems gradually adapt to new states of equilibrium in the interest of the conservation of muscle energy.

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