A STUDY OF THE RELIABILITY OF MEASUREMENTS OBTAINED FROM RADIOGRAPHS PRODUCED BY THE UPDEGRAVE TECHNIC OF TEMPOROMANDIBULAR JOINT RADIOGRAPHY

by

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INTRODUCTION

Numerous methods are available for obtaining a radiographic image of the temporomandibular joint. One method often used is the lateral oblique transcranial technic as described by Updegrave (33). This angulation gives the classic profile image that is usually envisioned when describing the anatomical relationships of the components of the joint. As in any radiographic projection, superimposed shadows of surrounding or overlying structures mask the clarity of the area of interest; and, the image distortions of the radiographed parts must also be considered when interpreting the radiographs of the temporomandibular joint.

One criticism of the lateral oblique method is that variations in the angle at which the central x-ray beam passes through the temporomandibular joint will bring about the illusion of varying the relationships of condyle to the walls of the fossa, or to other anatomical parts, even though these relationships may be constant. These differences in angulation are created by morphological variations of individuals as well as by the mechanical errors of positioning which are a part of any radiographic procedure.

Sources of error inherent in the Updegrave technic which might create apparent changes of relationship include: (1) misalignment of subject to film, (2) misalignment of target to subject--or to film, (3) inaccuracies involving a combination of these factors. The source and magnitude of error in this particular technic have not been studied. The accuracy with which measurements can be made from radiographs of the temporomandibular joint which are obtained by the Updegrave technic has not been demonstrated. The problem of repositioning a patient for purposes of serial study is an important one, and the exactness with which repositioning can be performed employing the equipment and prescribed angulations has not been revealed.

PURPOSE

The purpose of this study is:

1) To compare measurements of the temporomandibular joint gap on skulls with measurements obtained from radiographs of that articulation when employing first, the Updegrave technic and then, a modified Updegrave technic.

2) To compare the results of the measurements of the Updegrave technic radiographs with the measurements obtained from radiographs when employing a modified Updegrave technic, and to determine which method is more reliable.

REVIEW OF THE LITERATURE

The literature relevant to this thesis will be considered from a standpoint of variations of the lateral oblique technic of temporomandibular joint radiography. The radiographic findings and individual interpretations of those findings when employing this lateral angular direction of the central x-ray beam will be reviewed.

One of the early attempts at temporomandibular joint radiography was made by Sproull (31) who in 1933 employed a 23 degree sinus board and adapted it for his purposes by focusing the central x-ray beam 3 inches above the uppermost part of the ear on the side of the head opposite the joint being radiographed. In 1935, Gillis (10) reported some of the details of his technic in which the patient's head was placed on its side against the film cassette with the central ray directed "about 15 degrees downward and ... directed about 17 degrees posteriorly." Gillis reported a thinning out of the interarticular cartilage, discussed centric occlusion and centric relation and showed radiographs in which the condyle "rotates downward and backward, compressing the tissues adjacent to the ear."

The first reference to the mid-sagittal plane and its positional relationship to the cassette in temporomandibular joint radiography was made by Reisner (22) in 1936. His technic included a 15 degree angle board; and, with the head resting on the ear and the mid-sagittal plane paralleled to the board, the cone of the x-ray machine was placed 2 inches above and ½ inch in front of the external auditory meatus on the side of the head opposite the joint under study. Reisner's report is concerned to a large extent with the idea that the morphology of the joint is determined by the type of bite, and that changes will occur in the disc, condylar head and eminence. He also emphasized that one cannot expect to find a standard position of the condyle in the mandibular fossa according to the classification of the position of the teeth.

Lindblom (16), in 1936, employed an upright position of the patient to avoid displacement of the condyle if the teeth were not "kept tightly closed" during radiographic procedures. Illustrations are shown to describe the determination of the transverse axis of the condyle which the central beam follows. "It was then found that the line ... from above onto the horizontal plane ... is 15 degrees. Further, it fell obliquely from behind, making an angle with the frontal plane ... about 15 degrees." From these angles he constructed his "Beam direction indicator" which placed the cone of the x-ray machine in proper relationship to the head.

In 1937, Higley (13) described his apparatus which used calibrated scales to record the upright head position to facilitate exact repositioning. His angulation of the x-ray beam was based on his study of 250 skulls and an additional 2000 skulls by Maves at Western Reserve University. He contends that there is variation, but that the majority of condyles show a 20 degree angle with the transverse meatal plane (frontal plane) and a downward and inward 6 to 8 degree angulation with Frankfort.

Maves (17), in 1938, determined the transverse axis of each condyle by a "basilar view," but neither his radiographic equipment nor his technic is described. He also emphasizes the importance of repositioning the head for serial study, but he does not give his method of accomplishing this. His findings are summarized in this manner: "Hundreds of tracings of skulls have proved that the long axis bisects the median sagittal plane at various angles and therefore no average angle can be accepted for accuracy." Maves's method of showing changes in the temporomandibular joint consisted of superimposing tracings of the radiographs during bite opening procedures.

Schuyler (27) questioned the value of lateral radiography in 1939 with this statement: "While finding roentgenograms of the temporomandibular joint of great value, I consider that diagnosis and treatment planning from them alone to be subject to grave error." Pippin (18), on the other hand, in 1943, employed the lateral radiograph to establish a "base line" from the center of the auditory meatus to the lower margin of the orbit from which to judge malpositions of the head of the condyle in 100 patients. The relationship of the condyle to the line while the teeth are in centric occlusion is important in his classification. In this same period, Kurz (14) employed the laminagraphic technic of lateral radiography to establish a base line using the identical landmarks as Pippin. His laminagraphic equipment necessitated the patient's head being placed on its side with the zygoma and superior lateral border of the boney orbit on the table "in which case all the requirements for correct angulation are met." Once again the necessity for accurate repositioning is emphasized.

Schier (25) measured 200 skulls and reported a "new projection" angle based on the morphologic findings. In describing his "new technique" he states:

> It has been found that these three new or emphasized areas, uncannily serve as a planar base giving a determinant for an angular projection of the central ray which will most nearly conform to the transverse direction of the condyle head in the vertical and horizontal planes--or in its extremes, the descending inclination of the superior surface.

The three areas referred to are the high point of the zygoma, the gonion and the junction of the external oblique line and the lower border of the mandible. Schier's measurement showed that "a line at right angles to this (flat) plane would run parallel to the transverse direction of the condyle." Ennis (9), writing in 1945, questions the "roentgenologic study" of the temporomandibular articulation that had been made to date in that it had been "based on a few clinical facts and no scientific reasoning." Through his investigation, which consisted of radiographing skulls of infants at birth, he found that the condyles of the mandible vary in the same individual at birth.

Blume (2) reported in 1947 that when employing the Lindblom technic of temporomandibular joint radiography and using brass wires glued to important landmarks "the following areas were found to be the most easily discernable and constant: (1) junction of the lateral and middle thirds of the superior surface of the head of the condyle, (2) junction of the lateral and middle thirds of the glenoid fossa, (3) junction of the lateral and middle thirds of the articular eminence."

In 1950 and 1952, Ricketts (20, 21) described his laminagraphic technic. It was performed with the patient's head on its side and an average "cut" at a depth of 3.5 cm. This depth projected the center of the condyle, the entire ramus, the outer rim of the orbit, the zygomatic ridge, the ear canal, glenoid fossa, petrotympanic fissure, postglenoid process, articular eminence, and an area just lateral to the buccal teeth. Employing a tracing technic, Ricketts tabulated the following pertinent findings on 100 patients (200 joints): (1) there is no correlation between the size of the condyle and the size of the fossa, (2) the mean anterior joint gap is 1.5 mm., (3) the mean superior joint gap is 2.5 mm.

Collins (5), employing Riesner's technic of angulation, radiographed one skull with a wire on the condyle and lead strips laid on the fossa; and, he found that the most lateral border of the fossa and the middle of the condyle to be the areas to conform most to the anatomy of the parts as viewed on the radiograph.

The steps taken to improve the quality of the radiographs and simplify the technic of temporomandibular joint radiography were described by Updegrave (32) in 1950. These improvements included a lead diaphragm and aluminum filter in place of the plastic cone on the x-ray machine as well as a 15 degree angle board with a slide for the 8 x 10 cassette. By 1951 (33) a protractor assembly had been added to the side upright arm to record the sagittal plane of the head, a leaded mask over the slide tunnel to permit 6 exposures on one film and the sagittal plane of the head was permitted to rotate slightly down toward the cassette (about 12 degrees) so that the boney prominences (after Schier) were touching the flat surface of the slide tunnel.

In Sarnat's book <u>The Temporomandibular Joint</u>, published in 1951, Sicher (30) described the variations in the morphology of the condyle:

> The condyle is about 15 to 20 mm. long and 8 to 10 mm. thick. Its long axis is at right angles to the plane of the mandibular ramus and deviates, therefore, from the frontal direction. The two axes of the condyles form an obtuse angle varying from 145 to 160 degrees. If extended medially and posteriorly, the axes of the condyles would cross approximately at the anterior

> circumference of the foramen magnum. The condyle is strongly convex in an anteroposterior direction and slightly convex mediolaterally. The latter convexity is often replaced by a more or less tent-like formation of the upper surface of the condyle which then is divided into a medial and a lateral slope by a variably prominent sagittal crest.

Amer (1), who in 1952 reported the results of his investigation of 35 individuals and 19 dry specimens, raises the question of what is to be called "normal." By employing a "submento-occlusal" technic and measuring angulations from the basilar view, he found in the human beings that: (1) in five cases only, the condyle on one side has the same angulation with the horizontal plane as the condyle of the other side; (2) the range of variation in the angulation of the right and left condyles may be as much as 19 degrees; (3) the extensions of the lateromedial axis of the condyles form an obtuse angle open to the front and vary from 110 degrees to 166 degrees; (4) the extensions of the lateromedian axes in 24 cases meet in various locations in the foramen magnum, and in 11 cases they meet in different locations outside the foramen magnum. In a combined photographic and radiographic study of the condyles of the dry specimens, Amer reports that no two condyles in the same specimen are alike in size, form or position. In only two specimens were right and left condyles equal in the angulation of their horizontal axes. The lateromedian axes of these condyles ranged from 112 degrees to 159 degrees. The average length and width of the 110 condyles in this study were 2.1 cm. for the lateromedian axis and 0.75 cm.

for the width.

Donavan (7, 8), reporting the progress and results of his studies in 1953 and 1954, also accents the great variability in individuals and says that "because of these variations, it is impossible to obtain a useful profile view of the relation of the condyle, eminence and fossa in all cases." For radiographing the temporomandibular joint, Donavan's equipment included a Broadbent-Bolton x-ray tube combined with a head holder of original design. The head holding device facilitated accurate repositioning for serial study. This method of producing radiographs was tested by Ruskin (23) in 1952 who found: (1) the junction of the lateral and middle thirds of the fossa formed the lower border of the fossa outline on the radiograph, (2) the Donavan orienting device permitted accurate duplication of temporomandibular joint radiographs, (3) it was not possible to measure the actual distances between points on condyle and fossa from only the radiograph, (4) the mediolateral distances between corresponding points on the condyle and fossa compared favorably with the thickness of the sections obtained by the use of laminagraphy. In these studies, the x-ray and cassette are aligned in much the same manner as in the Lindblom technic--the central beam making a horizontal angle of 15 degrees and a vertical angle of 19 degrees with the hinge axis of the condyles. Donavan concludes that a functional analysis is more valuable than a measurement of the various joint gaps in centric occlusion.

Updegrave (34, 35), writing in 1953, reveals that the lateral oblique technic of temporomandibular joint radiography is of value for the following purposes: (1) demonstrating the condyle-fossa relationship in all excursions of the mandible; (2) outlining the contours of the condyle, fossa and eminence which should be closely examined for erosion of calcific deposits; (3) checking the positioning of the condyle in the fossa during the alteration of the maxillomandibular relationship; (4) disclosing developmental defects, subluxations, luxations, ankylosis, fractures or other traumatic injuries.

Grewcock (12) devised a "simple technique" employing an office x-ray machine and a hand-held cassette. With the Frankfort plane parallel to the floor and the head vertically upright, the cassette is laid flat against the cheek. "The cone of the tube ... is applied directly to a point 1 inch above the upper border of the pinna, on a line immediately above the external auditory meatus. When directed straight at the opposite condyle head, this gives an approximate downward deflection of between 20 degrees and 25 degrees and a forward inclination of 15 degrees to 20 degrees, towards the face."

Craddock (6), in 1953, agreed with the 15 degree angulation in two planes and the upright position of the patient. In a random selection of 26 mandibles, he found that "orientation of the condyles approaches closely to bilateral symmetry over the whole range of inclinations in both planes." The term "approximate symmetry" is used as the descriptive term in this study to describe the normal condyle-fossa relationship. Measuring 60 joints of 30 normal adults, Craddock found that the "approximate dimensions of the interarticular space" with the teeth in occlusion averaged 2.0 in the anterior, 3.0 superior and 2.5 in the posterior joint gaps. In 1955, Brandrup-Wognsen-employed a transparent celluloid plate with a hole in it through which he aimed the central beam. The hole was located by trigonometric formulae, but the beam was directed at a standard 15 degrees downward and forward.

Reber (19) experimented in 1956 to evaluate the distortion of the radiographic image when using the Updegrave technic by placing a series of fine wires on the superior surface of the condyle and the roof of the glenoid fossa. He states:

> The results of this study indicate that the temporomandibular joint radiograph does not represent an anterioposterior section through the center of the joint. Instead, the radiographic image is generated by points in widely separated planes. The results indicate that the radiograph presents a fairly true image of the tympanic plate, the lateral border of the glenoid fossa and the lateral third of the anterior and posterior eminentiae.

Chayes and Finkelstein (4) used Updegrave angulations but modified their equipment so that the patient was in an upright position. In a comparison of their technic with that of Updegrave, they pointed out that in the latter it was difficult to position some arthritic patients. Other shortcomings, they claimed included: (1) the ear plug could not be seen by the operator which in some cases resulted in incorrect positioning of the patient, (2) the tube required alignment by eye for each pair of exposures which was time consuming, (3) the sagittal plane readings were very inexact. In contrast, their equipment had the patient in a simple upright position, it was pre-focused and aligned, there was a marking system on the cassette, the procedure was short and the patient could be seated in the dental chair or on a stool.

In 1956, Lawther (15) used the basic Broadbent-Bolton cephalometer but designed a head holder specifically adapted for temporomandibular joint radiography. In this special holder, the porionic axis is 10 degrees downward and 12.5 degrees forward relative to the central ray which enters "a little above and behind the ear and leaves at the external acoustic meatus on the side being filmed." From radiographs of 32 men (10 edentulous, 11 in the 20 year age group and 11 in the 30 year age group), he established "standards" after making four radiographic exposures on each patient--1 in centric, 2 in rest position and 1 with the mouth wide open. Tracings were made and oriented on porion, the superior surface of the sphenoid and the orbit. Linear measurements were made which included: (1) the height of the fossa, (2) the distance from the condyle to the height of the fossa (superior joint gap), (3) the relationship of fossa height to the porion-orbital line and (4) the movements of the condyle. Angular measurements were: (1) the posterior border of the ramus to the porion-orbital line and (2) the slope of the articular eminence to this base line. His findings state that there was "no appreciable differences between the 20 year age group and the 30 year age group." The average measurement for the superior joint gap was 2.61 mm. for the "standards" in centric occlusion, while in a group of 18 patients with temporomandibular joint disturbances, the average gap was under 2.0 mm. in the affected joint.

Goldblatt (11), in 1957, made a three dimensional study of the joint gap by casting acrylic models of the temporomandibular articular region in 25 dry specimens. He found that the greatest conformity existed in the "middle sections ... whereas the more medial and lateral sections showed greater variation." In this same year, Updegrave (36) reemphasized that there was no correlation of joint with condylar function, but that "it appears that muscular function dictated largely by jaw and tooth relations, is the dominant factor, the joint being secondary." He further stresses the importance of a functional radiographic analysis.

Sairenji and Yanagisawa (24) reported in 1958 that their method of radiography featured a cassette holder and ear rod attached to an office machine. The patient is upright, and their point "P" of entry of the central beam is on the opposite side of the skull 2 cm. superior to the auriculo-auditory (Frankfort) plane and 1.5 cm. anterior to porion at an angle of 25 degrees. After remeasuring 8 Japanese skulls 21 times, they report: "Is observed no difference on right or left with level of significant[sic] under 5%."

Zech's (40) study, in 1959, compared three technics of temporomandibular joint radiography. The first approach was in using a modified "Law projection for mastoid sinus" in which the central beam is at 15 degrees and approximately 2 inches above and behind the external auditory meatus. The second method was that of the original Updegrave technic using an angle board with the sagittal plane of the head parallel with the cassette, while the third method was that described as the "McQueen-Dell technic" with the beam directed upward at 10 degrees and backward at 5 degrees through the sigmoid notch. Regarding the Updegrave technic, Zech says:

> In malocclusive types of temporomandibular joint disturbances, this technic gives the most information. It is possible to determine with considerable accuracy the mobility of the condyle, its relationship in the fossa and its relationship to the eminentia during closed and open positions. Osteoarthritic changes of the condyle and erosion of the articular eminence are readily observed with the Updegrave method. This is a gratifying technic to use, for the results are uniformly good.

The first method, according to Zech, is difficult but gives the truest representation of the size of the condyle, while the McQueen-Dell technic is classified as "good."

In Shore's (28) book, published in 1959, he describes a 10 degree angle board with a 15 degree x-ray machine setting giving a total horizontal angulation of 25 degrees. He calls this the "basic principle" of the lateral technic. The central beam enters the head 60 mm. above the superior edge of the external auditory meatus, the patient's temple rests on the cassette with the sagittal plane parallel to it and the Frankfort plane (determined from external landmarks) is parallel to the top of the film. Shore justifies this technic with the statement: "It has been found that the superior surface of the condyle head,... and the inclination of the glenoid fossa ... are at an average angle of approximately 25 degrees to the horizontal."

Updegrave (37), writing in Dental Clinics of North America, 1961, admonishes that radiographic examination may fail to disclose evidence of abnormality or pathosis of the joints in that the pain may be neuromuscular or capsular in origin, "so unless the condition has been sufficiently severe and of long enough duration to affect the bone ..." no changes will be apparent.

In 1961, Yale, Rosenberg, Ceballos and Hauptfuehr (39) measured 25 skulls to determine the angulation of the condyle. They then tested three methods of radiographing the condyle to determine "condylar image distortion and geometric condylar image enlargement." The condyles fell in three groups according to their horizontal and vertical condylar angles. All three groups had horizontal angles greater than 90 degrees with the frontal plane but varied in their vertical angulation from -6.9 to 5.1 degrees. Of their three radiographic methods, they reveal that "corrected cephalometric laminagraphy was found to produce the most accurate lateral roentgenographic image of the mandibular condyle."

Writing in 1962, Schier (26) criticizes the technics which employ angulation of central beams from in front of the ear implying that it is at "cross purposes" with the angulation of the condyle. At this time he introduced a technic in which the head is erect, the face touching the cassette at three points (described in 1943), the central beam directed downward at 15 degrees and 19 degrees to the frontal plane from a point somewhere above and behind the external auditory meatus as determined by the "sagittal aligner." Updegrave (38) at this same time looks forward to a "correlation of cephalometric with temporomandibular joint roentgenograms ... which might be used to clarify some current controversial issues."

In view of the fact that cephalometric radiographic technics have been tested for accuracy many times and their limitations are known, it is now necessary to test the accuracy of certain lateral oblique radiographic technics that are employed for observing the temporomandibular joint region.

METHOD AND MATERIALS

I. Preparation of skulls

A. Ten dry skulls, each with a minimum of 26 teeth to assure a good centric occlusion relationship, were obtained from the Department of Anatomy of the School of Medicine, Western Reserve University. These were adult skulls, but otherwise there was no regard to age, sex or size of the specimen.

B. Each skull was prepared for radiographing in the following manner:

1. Centric occlusion was determined by articulating the teeth and reference lines were drawn on the opposing molars and incisors.

2. After disarticulating the mandible, the mediolateral long axis of the left fossa was determined and measured for length. The junction of the middle and lateral thirds of the superior fossa wall was marked in pencil--the marks extending over the anterior and posterior eminentiae at right angles to the mediolateral long axis.

3. Pieces of beeswax 3-4 mm. thick were softened by flaming lightly and were adapted to the right

and left fossae. The wax was trimmed to extend only over the posterior slope of the anterior articular eminence, as far as the squamotympanic fissure posteriorly and laterally as far as the line marking the junction of the lateral and middle thirds.

4. Frankfort horizontal was determined from the external landmarks of the infraorbital ridge and the highest contour of the external auditory meatus. A flexible straight edge was laid at these two points and a pencil line drawn across the region of the temporomandibular joint.

5. Fine lead wire, .020 in. in diameter, was adapted to the height and posterior slope of the anterior articular eminence at the previously measured site of the junction of the lateral and middle thirds (the line continuing out of the fossa).

6. A small metal marker shaped like an inverted "T" was fashioned from .021 x .025 stainless steel wire. The length of the cross members varied from skull to skull according to the mesiodistal width of the fossa as well as the depth with which the condyle seated into the fossa. This wire was placed flat against the lateral margin of the beeswax with its base paralleled to Frankfort and its upright arm

resting in the deepest point of the left fossa (figure 1).

7. The wax in the fossa was softened by brush flaming, the disarticulated mandible was brought into position by articulating the teeth into centric occlusion while the condyles were observed to seat firmly into the wax in the fossae.
8. The teeth were "sticky-waxed" together in centric occlusion.
9. From observations on twenty lateral cephalograms of patients, it was determined that the tip of the nose was approximately opposite the center of the nasal cavity; therefore, this mid-point was pencil marked on each skull to represent the tip of the nose.
10. A metal ball, .078 in. in diameter, was fastened with sticky wax to the highest contour of the external auditory meatus to represent porion (figure 2).

II. Radiographic procedure (Trials number 1 and 2, <u>No Pointers</u>).

A. Equipment

1. A general Electric dental x-ray machine (model #90-II).
2. A 1962 production model of the "T M J Board" designed by Dr. W. J. Updegrave and manu-

factured by the David Simmonds Company.

3. An 8 x 10 cassette with par speed intensifying screens and Kodak Blue Brand film.

B. Procedure

1. The directions furnished with the Board for alignment of the x-ray machine and positioning of the cassette for a 6 exposure technic were followed. (These directions are similar to Updegrave's (34).

2. The skulls were positioned singly on the Board. In every instance the high points of the zygoma and ramus (as described by Schier (25) and Updegrave (34) automatically determined the relationship of the sagittal plane to the film. The position of the nose tip and the angle of the sagittal plane were recorded, as well as the angle that the mid sagittal plane made with the film when viewed from the top. This latter angle was read with the Cephalometric Protractor.

3. Each skull was identified by a lead number and then exposed for 1/20th second at 10 milliamps and 60 kilovolts.

4. Five days after the initial trial, the series of ten skulls were radiographed in an identical manner and labeled "Trial 2, No Pointers." (figures 3 and 4).

III. Modification of equipment

A. The outer diaphragm ring was drilled and threaded to accommodate two rods, the holes being placed at 90 degrees to each other. Threaded, hollow rods, 0.125 in. in diameter and 4½ inches long were screwed into the holes. Solid brass rods 4 inches long were inserted into the hollow rods and the length of their protruding, pointed ends were controlled by threaded, knurled screws threaded through the outer tubes. This arrangement permitted a more exact centering of the x-ray machine relative to the subject (figure 7).

B. A similar pointer arrangement was prepared for the side upright (figures 5 and 6), so that the pointed end could be adjusted to contact the tip of the nose (in this case the pencil mark in the center of the nasal cavity).

C. A metal ball marker was implanted in the center of the ear rod.

IV. Additional equipment

A. A Boley gauge with a groove ground across one of the beaks--that beak filed down to measure exactly 1 mm. across.

B. A transparent millimeter grid which had been tested as being accurate to 1%.

C. Depth gauges which were #4 and #5 Kerr root canal reamers with small pieces of rubber dam material on the shafts.

D. Dividers on which the pointed ends were ground and flattened, so that the ends were parallel to each other (figure 8).

E. A Cephalometric Protractor manufactured by the Unitek Corporation.

V. Radiographic procedure (Trials number 1 and 2, <u>With Pointers</u>)

A. Equipment

1. The identical equipment as that described in Part II was employed with the exception that the modified pointer system (Part III) was attached to the x-ray machine and Board.

B. Procedure

1. With the pointers touching their designated landmarks, the skulls were positioned singly and radiographed in the same manner as described in Part II.

2. Seven days later, this procedure was duplicated and labeled "Trial 2, With Pointers."

VI. Measurement procedure

A. Skull measurement

1. The skulls were disarticulated to expose the beeswax which now had the impression of the superior surface of the condyle in it (figure 1).

2. The depth gauges were now employed to measure

the thickness of the wax on the line of the junction of the middle and lateral thirds of the fossa in the posterior, superior and anterior joint gap areas. (The "anterior joint gap" is defined as that region between the anterior surface of the condyle and the posterior slope of the anterior articular eminence. The "superior joint gap" is defined as that area between the highest point of the condyle and the deepest portion of the concave surface of the roof of the fossa. The "posterior joint gap" is visualized as that area between the posterior surface of the condyle and the anterior surface of the posterior articular eminence--1 millimeter above the squamotympanic fissure.)

3. One week after this "m_1" set of measurements, the joint gaps were remeasured to give an "m_2" set of measurements.

B. Measurements on radiographs

1. Employing the transparent millimeter grid, the anterior, superior and posterior joint gaps were measured. The same anatomic landmarks that were used when making the skull measurements were now used on the radiographs. The gaps were gauged by overlaying the millimeter grid on the radiographs and locating

the most distinct boney outlines of the margins of the fossa and condyle (plate 1).

2. One week later these T_1 (Trial number 1) No Pointer radiographs were again measured to give a "T_1m_2NP" (Trial 1, measurement 2, No Pointers) set of numbers.

3. Subsequently, the radiographs obtained when using the modified technic were measured in the same manner to give a "T_2m_1WP" (Trial 2, measurement 1, With Pointers) and a second set of measurements labeled "T_2m_2WP."

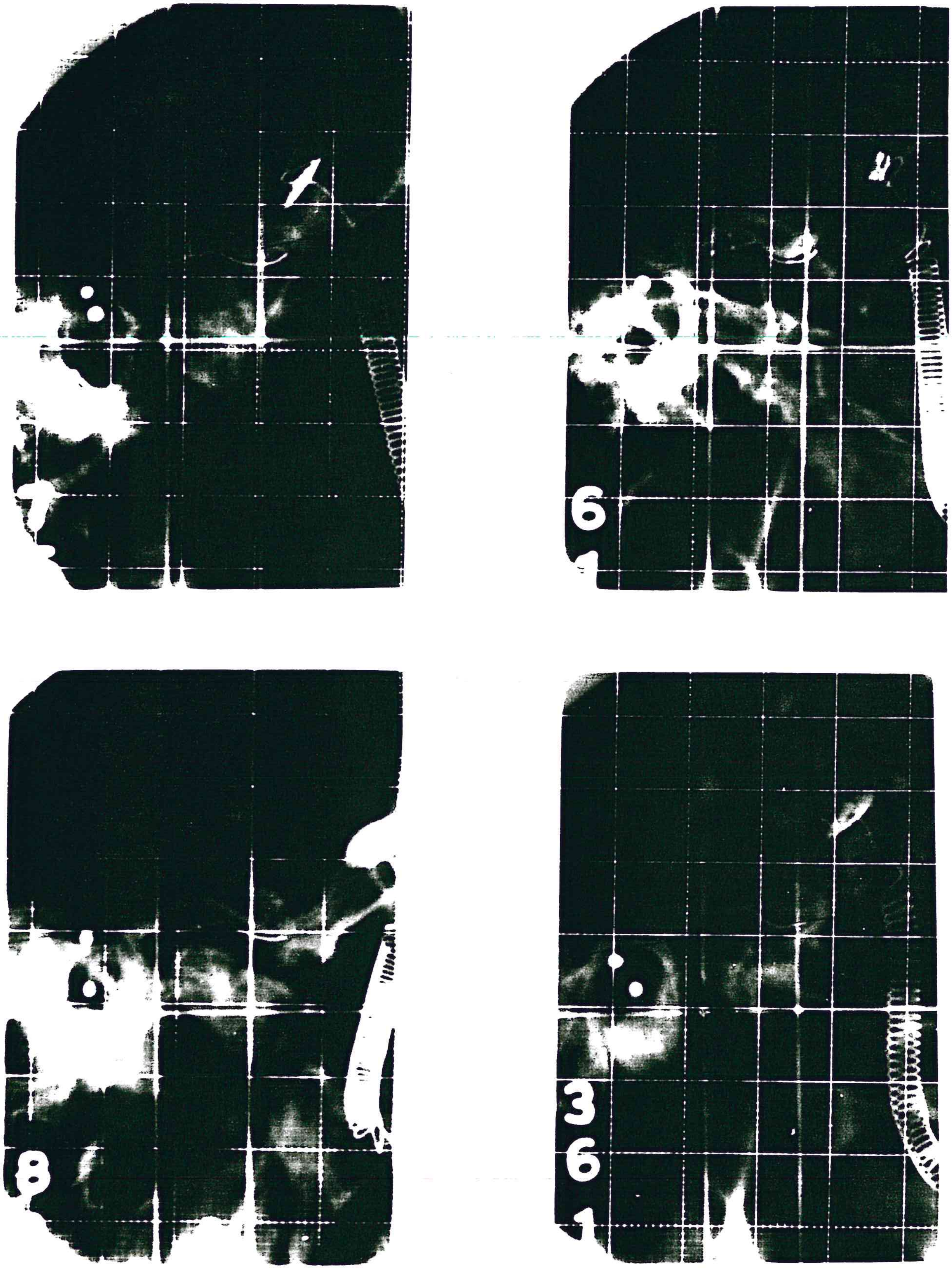
C. Recording the measurements

1. All measurements were recorded independently on separate pages; and, on completion of the measuring procedures these figures were transferred to summary pages (table 1) for statistical analysis.

VI. Statistical analysis procedure

An analysis of data was carried out for all measurements, namely: (1) the m_1 and m_2 of Trials 1 and 2 in the No Pointers experiment, (2) the m_1 and m_2 of Trials 1 and 2 in the With Pointers experiment and (3) the m_1 and m_2 of the skull measuring procedures. The analyses were performed to test: (1) whether a difference existed between the measurements, and (2) whether a difference existed between the No Pointers and the With Pointers methods. The first of these two tests revealed to what degree the procedure for the measurements had been standardized. The second test revealed whether there was any difference between the NP and WP methods. If there was a difference, it pointed out which one was a better method.

PLATE I



Radiographs with measuring grid superimposed. The two upper figures show sharply defined boney outlines, while the two lower figures are examples of poor delineation of boney outlines.

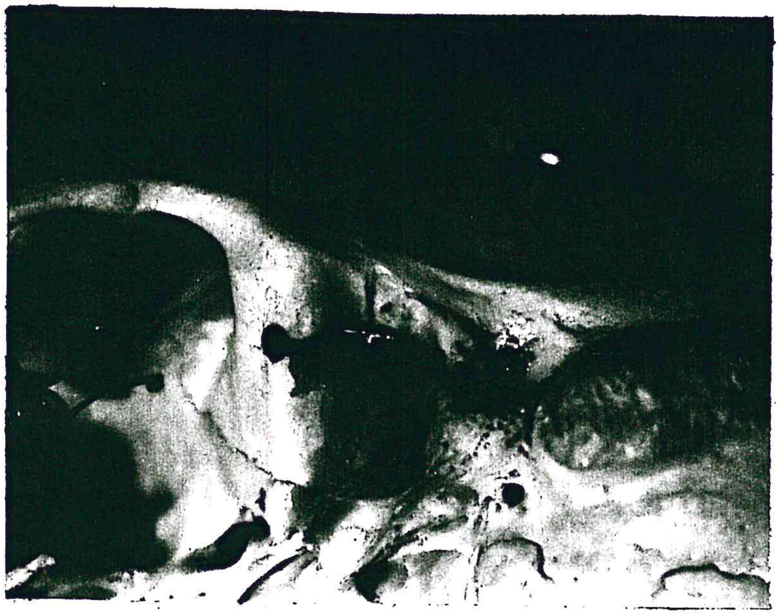


Fig. 1
Superior
Wall
(from below)

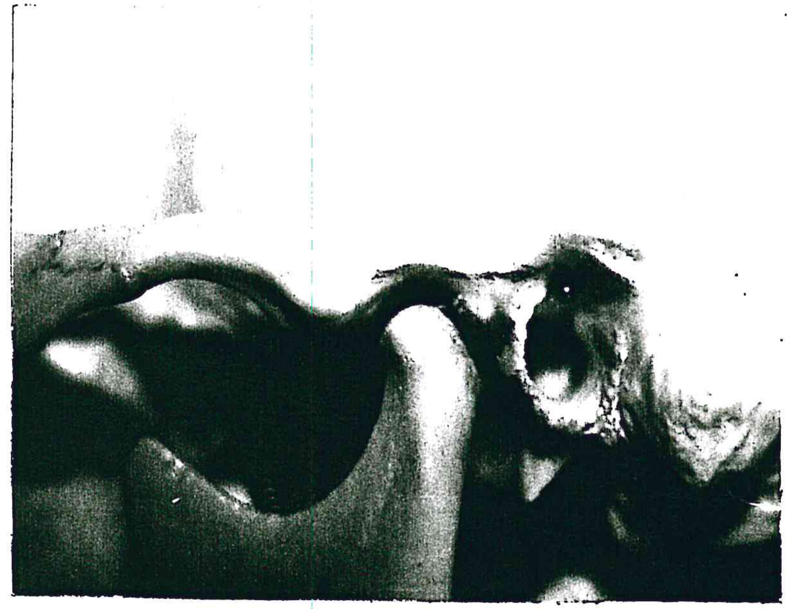


Fig. 2
Lateral
View

Fig. 3
No Pointers

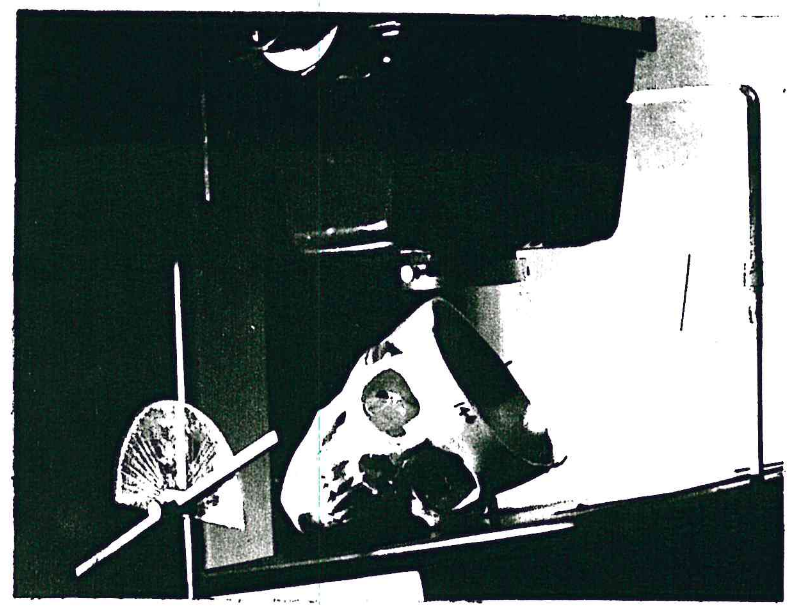


Fig. 4

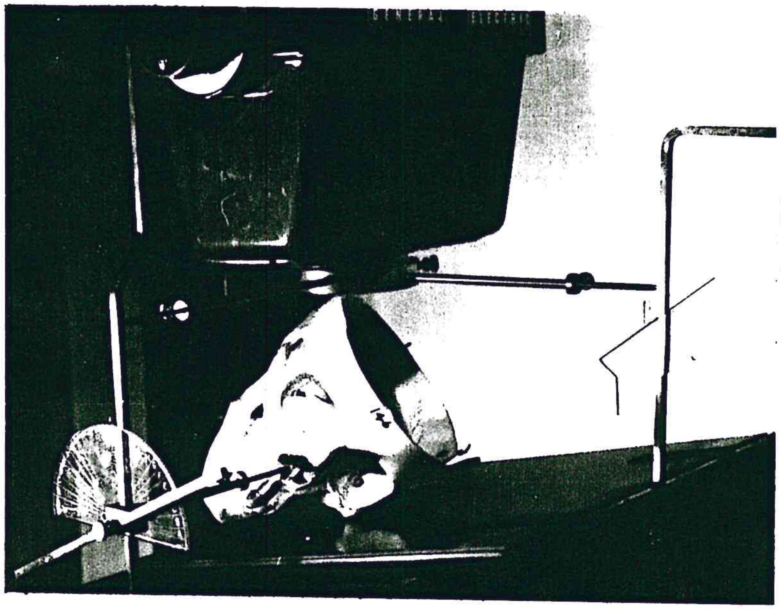
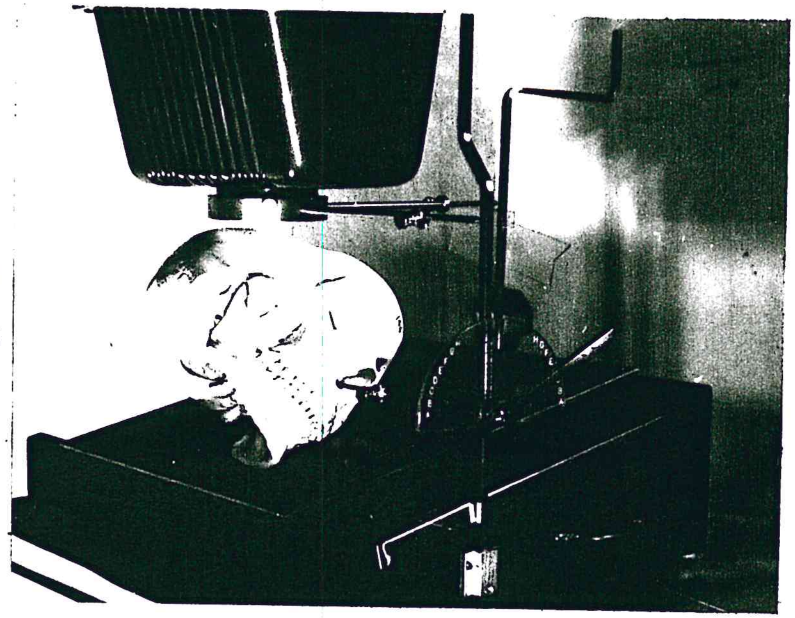


Fig. 5

With Pointers

Fig. 6



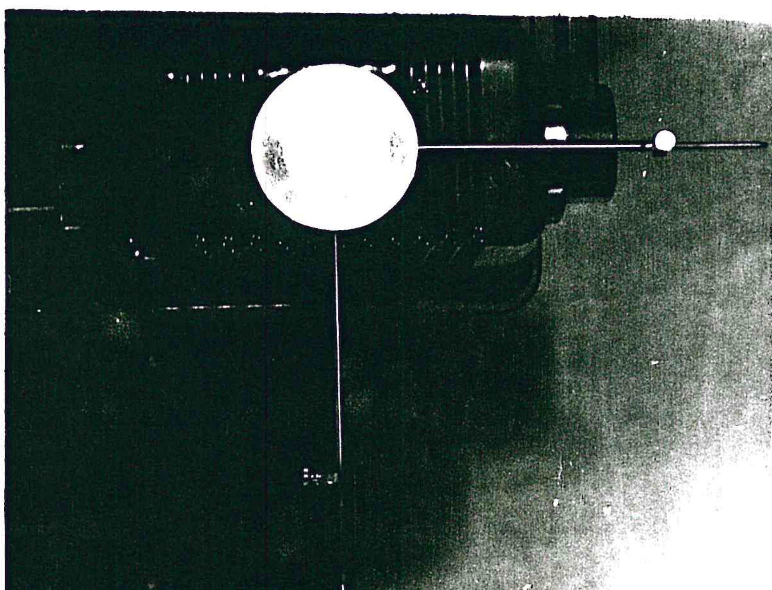
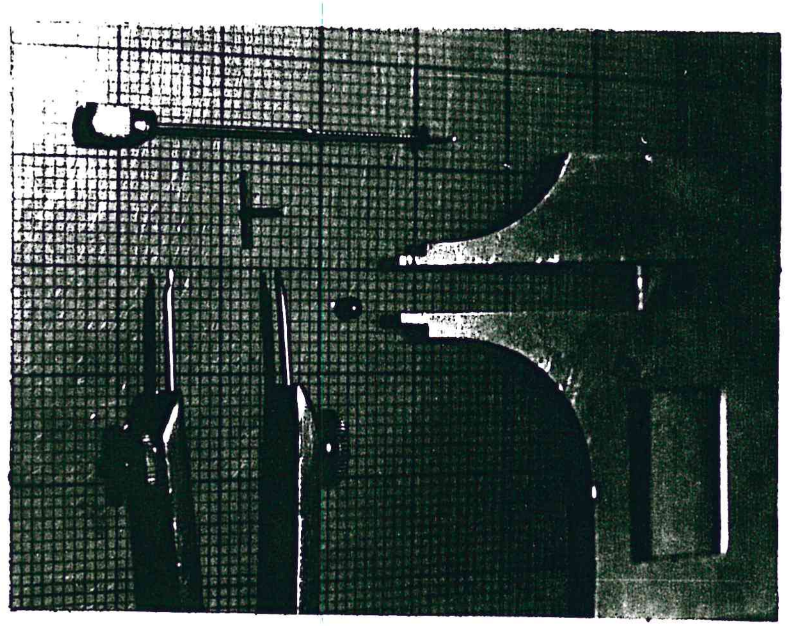


Fig. 7
Auxiliary
Pointers

Fig. 8
Measuring
Equip.



FINDINGS AND DISCUSSION

In the analysis of the anterior joint gap, no significant difference was found between the first and second measurements on the radiographs in Trial 1 or Trial 2 with or without pointers (tables 2 and 3). Nor was a difference found between the m_1 and m_2 of the anterior joint gap measurements on the skulls (table 8A).

The standardization of the measuring procedure was again demonstrated in that there was no difference shown between the first and second measurements within the two trials on the superior joint gap (tables 4A,B and 5A,B). There was however, a significant difference between the first and second trials in the No Pointers procedures (table 4C). The With Pointers measurements showed no difference between T_1 and T_2 (table 5C).

The findings which the posterior joint gap measurements provided (tables 6A,B and 7A,B) were very similar to those of the superior gap. Here too, the difference between the T_1 and T_2 of the No Pointers experiment was significant (table 6C), while the With Pointers trials showed no difference (table 7C).

Since no significant differences were found between measurements and trials in the case of the anterior joint gap, it was possible to do a combined analysis using the average measurements (table 9). This analysis tests whether there is any difference between the skull, the No Pointers and the With Pointers methods using the average values of the measurements on the radiographs (with and without pointers) and the average of skull measurements. The average value can be taken since there is no difference between T_1 and T_2. In the superior and posterior joint gap cases there is a difference between T_1 and T_2 for measurements without pointers, so that no true value can be given to these figures. Also, since the sample of ten is too small to reveal any significant difference between the skull and the With Pointers measurements, a combined analysis was not done for these two sets of measurements.

The combined analysis for the anterior joint gap (table 9) shows no significant difference between all measurements and methods; but, when the overall variation in the measurements of the anterior joint gap for all methods was determined, the No Pointers measurements appeared to be somewhat different from the With Pointers and skull measurements even though analysis of variance does not reveal this. Therefore, a correlation analysis was done between actual skull measurements and the With Pointers and No Pointers radiographic measurements.

This correlation analysis shows that Without Pointers the correlation of anterior, superior and posterior is 0.1, .65 and .78 respectively. The With Pointers correlation is .75, .78 and .77. Table 10 summarizes these correlations while graphs 1, 2 and 3 illustrate this.

Graph 1(a) indicates that there is practically no correlation between the actual skull measurements and the radiographic measurements without pointers. Graph 1(b) indicates that there is a high correlation between the actual skull measurements and the radiographic measurements when the With Pointers method is employed. Graphs 2(a) and 2(b) indicate that there is high correlation between skull measurements and radiographic measurements with either method when dealing with the superior joint gap. Graphs 3(a) and 3(b) indicate that the same is true in the case of the posterior joint gap.

It is apparent that the central x-ray beam passes through the fossa at various angles to the condyle due to morphological differences in subjects. The degree of distortion of the radiographic image in the various joint gap regions has been summarized in table 11. This correlation is based on the angle that the central beam makes with the transverse axis of the condyle.

For the anterior joint gap, the correlation shows that the image distortion has no relationship to the angle that the x-ray makes with the transverse axis. In the superior joint gap the correlation shows that there is some relationship between distortion and angulation, but the optimum angle cannot be stated because of the small sample.

In the case of the posterior joint gap, there is also some relationship between distortion and angulation; but, in that the superior joint gap shows a positive correlation and the posterior joint gap shows a negative correlation, it can be stated that the optimum angle for radiography of the superior joint gap is not the same as for the posterior joint gap (whatever that angulation might be). It is further shown in this table that there is very little difference when appraising these distortions, whether the No Pointers or the With Pointers method is used.

Table 12 summarizes repositioning measurements. The Frankfort horizontal readings are from the radiographs. Although there is no significant difference at the 5% level, at the 10% level it is significant. If more trials of this type are made, it is highly probably that the With Pointers reading will be more consistent than the No Pointers readings. The vertical scale and sagittal scale readings are from the side protractor assembly. On the vertical scale, to which the auxiliary pointer is attached, the repositioning error is reduced by 75% when the pointers are in use. This is a significant difference. On the sagittal scale there is also a significant difference, however, it is in favor of the No Pointer technic. It is probable that this error could have been in favor of one or the other technics, in that the sighting of the sagittal angle is at best a crude method to which another set of auxiliary pointers might be of aid.

As early as 1937, Higley (13) stated: "The idea has been advanced that the physiologic rest position of the mandible remains constant throughout life; and, that the condyle-fossa relationship, in this position, may, therefore, be taken as the guide in repositioning the mandible." The exhaustive studies of Ricketts (20, 21) and Donavan (7, 8) confirmed this opinion, but their research further pointed out that there was no correlation between type of bite and path of closure from rest position.

It is generally agreed that in many cases abnormal tooth contacts during the act of swallowing or chewing eventually lead to temporomandibular joint disorders. The prospect of locating these lateral shifts in radiographs is not good, as pointed out by Shore (28). Besides, lateral shifts are best observed clinically in deviated paths of closure as well as through use of functional wax bites. Ricketts stated that "the least variable condition proved to be the position of the condyle in the fossa when the teeth were clenched."

The tilted position of the head as employed in the Updegrave technic has been shown to forego an accurate rest position due to gravitational forces acting on the mandible. Since the rest position is generally accepted as relatively unchanging and since it would be inaccurately registered in the tilted head position of this technic, it was felt that a static study of joint gap measurements with the teeth in occlusion was in order. It is the changed relationships of the occluding teeth that serve in many cases to precipitate disorders of the temporomandibular joint.

Amer, Donavan, Ricketts, Lawther, Schier, Updegrave and many investigators not included in the Review, have shown that variation from person to person is the rule and not the exception. Because of this, it is not possible to describe the normal position of the condyle in the fossa. The condyle has been described as being located in the extremes of posterior relationship to a position which abuts the anterior articular eminence. Therefore, it is more logical to accept the position of the condyle in the fossa as normal when the individual is comfortable and asymptomatic, and consider that position which one finds in the ailing temporomandibular joint as abnormal for that individual.

The attempt to correct the position might be in an arbitrary direction; but, once located, a registration of that position radiographically serves as a valuable record in the event of further disabilities and may be considered the normal for that patient.

The mention of the word "normal" opens a floodgate of opinions. Webster defines normal as "the usual condition, degree, quantity, or the like." Ennis (9) states:

> From what we now know as fact, we must realize that to define the normal temporomandibular articulation from the roentgenogram is beyond our limitations. The question may be asked, what is normal? And when it is defined we can immediately show many cases that are not covered by the definition, yet may be classed as normal for that individual. I am afraid the symptoms lead the clinician to an interpretation of the roentgenogram. To say that the head of the condyle should be in a certain relationship to the eminentia articularis,

or so many millimeters this way or that, to be normal in the roentgenograms, is a misstatement of fact.

The temporomandibular joint radiograph, then, must find its principle use as a means of recording the "relative position, and, hence, changes in relative position" as pointed out by Craddock (6). But, as Pippin (18) pointed out, "it is not possible and, neither is it necessary, to make a correction of a malposed condyle to an infinitesimal fraction of a millimeter to its original normal position." It is concluded, therefore, that the value of radiography is in its ability to observe the relative position of the condyle to the confines of the fossa and subsequently record any changes in the relationships.

Updegrave warns of overinterpretation, while Pippin and others note that the radiograph of the temporomandibular joint is to be employed as the final word in determining relationships.

What are the criteria by which a lateral radiograph of the joint to be judged? Is it an accurate portrayal of the joint gap, and if so, of what value is a knowledge of the size of the gap?

Craddock has implied that a radiograph properly exposed should show good delineation of the anatomical parts. It must be presumed that superimposition of the condylar image on the wall of the fossa or an apparent lack of a joint gap in an asymptomatic temporomandibular joint must be construed as an inaccurate portrayal of the true relationships of the joint. Schier summarizes the value of the radiograph and the criteria by which he judges it when he states:

> A joint picture can be extremely valuable, but it must be judged in terms of its aid in diagnosis and control in treatment. From the purely functional standpoint, the fact that a condyle appears retruded does not, in itself, indicate an abnormality. When such a disclosure is accompanied by an array of symptoms, which were the reason for taking roentgenograms, then the positional relationship becomes suspect. This position is accepted as a reference base for the patient. When, in the course of treatment, there is an attempt to alter the condyle position, it is possible to gauge and control those changes which will remedy function, and give relief by comparing the new position with the initial relationship or reference base. If with a correction of function the symptoms subside over a considerable period of time, it can be assumed that this new condyle-fossa relationship is roentgenographically acceptable for the patient.

This study has pointed out that the Updegrave technic of temporomandibular joint radiography, with slight modifications, facilitates measurement of the joint gap in an accurate manner. The reproduceability for purposes of serial study with the teeth in occlusion has also been demonstrated. It remains, however, to prove the reliability of this technic in a study of measurements on human beings. A study designed for this purpose is the next step for proving the practicality of the Updegrave technic in the measurement of joint gaps. A personal communication from Dr. Updegrave further suggests a correlation of cephalometric radiography with this particular technic of lateral oblique radiography, in order to reveal the varied relationships in the temporomandibular joint in different skeletal and dental types.

TABLE 1

SUMMARY OF SKULL AND RADIOGRAPHIC MEASUREMENTS

	Skull Measurements				Radiographic Measurements					
					No Pointers			With Pointers		
	Ant	Sup	Post		Ant	Sup	Post	Ant	Sup	Post
Skull #566										
m_1	1.4	2.9	1.5	m_1 T_1	1.7	2.4	1.9	1.2	2.5	1.0
				m_1 T_2	1.7	2.0	1.9	1.8	1.8	2.0
m_2	1.5	3.1	1.6	m_2 T_1	1.6	2.2	1.9	1.8	2.0	1.9
				m_2 T_2	1.6	1.9	1.2	1.7	1.8	1.9
Skull #367										
m_1	2.2	4.1	2.4	m_1 T_1	1.2	3.1	1.9	0.6	3.1	1.9
				m_1 T_2	1.1	3.0	2.2	1.3	3.0	2.0
m_2	2.1	4.0	2.1	m_2 T_1	1.4	3.0	1.9	0.8	2.9	1.9
				m_2 T_2	1.1	3.1	2.4	1.3	2.9	2.0
Skull #361										
m_1	1.5	2.7	2.7	m_1 T_1	1.6	2.2	0.9	0.0	1.9	0.6
				m_1 T_2	0.8	2.1	1.4	0.0	2.2	1.1
m_2	1.5	2.2	2.1	m_2 T_1	1.6	2.1	1.2	0.6	1.9	1.5
				m_2 T_2	0.6	2.0	1.7	0.6	2.1	2.0
Skull #344										
m_1	2.0	3.4	1.7	m_1 T_1	1.9	2.0	1.9	1.8	2.1	2.0
				m_1 T_2	2.1	2.1	2.6	1.8	2.2	1.7
m_2	1.8	3.2	1.5	m_2 T_1	2.0	2.2	2.3	1.6	2.2	1.8
				m_2 T_2	1.9	2.7	2.9	1.8	2.3	2.7

TABLE 1--Continued

Skull Measurements						Radiographic Measurements					
						No Pointers			With Pointers		
Skull #583	Ant	Sup	Post			Ant	Sup	Post	Ant	Sup	Post
m_1	3.8	4.1	4.7	m_1	T_1	1.8	3.7	3.6	2.9	3.0	3.0
					T_2	1.1	3.4	4.0	3.1	3.3	3.5
m_2	3.5	4.3	3.7	m_2	T_1	1.2	3.6	3.9	2.9	3.2	3.0
					T_2	1.1	3.8	4.0	2.9	3.6	3.0
Skull #255											
m_1	1.6	2.3	3.1	m_1	T_1	1.1	1.9	2.7	1.4	2.3	2.1
					T_2	1.6	2.2	3.0	1.6	2.6	2.9
m_2	1.2	2.7	3.1	m_2	T_1	1.3	2.1	2.8	1.6	2.0	2.6
					T_2	1.4	2.0	3.0	1.4	2.0	3.0
Skull #340											
m_1	1.1	2.6	1.7	m_1	T_1	1.8	1.9	0.9	1.1	1.7	1.0
					T_2	1.6	2.0	1.4	1.3	1.5	1.0
m_2	1.3	2.5	1.8	m_2	T_1	1.2	1.8	1.0	1.8	2.0	1.0
					T_2	1.7	1.8	1.8	1.0	1.2	1.9
Skull #146											
m_1	0.3	2.8	1.3	m_1	T_1	0.7	2.8	0.2	0.5	2.5	0.3
					T_2	0.7	3.7	0.6	0.8	3.0	0.2
m_2	0.6	2.7	1.5	m_2	T_1	0.8	3.2	0.2	0.0	2.1	0.4
					T_2	0.7	3.0	0.9	0.6	2.8	0.5

TABLE 1--Continued

Skull Measurements				Radiographic Measurements							
						No Pointers			With Pointers		
Skull #155	Ant	Sup	Post			Ant	Sup	Post	Ant	Sup	Post
m_1	1.1	2.5	2.9	m_1	T_1	2.2	3.1	2.1	1.6	2.4	1.9
					T_2	2.2	3.0	2.1	1.9	3.2	2.0
m_2	1.4	2.4	2.9	m_2	T_1	2.3	3.0	2.0	1.5	2.6	1.3
					T_2	2.1	3.0	2.0	2.1	3.1	2.0
Skull #576											
m_1	1.4	3.2	2.5	m_1	T_1	1.9	2.7	1.6	1.7	3.1	1.6
					T_2	2.1	3.1	1.0	1.9	3.1	1.7
m_2	1.6	3.3	2.0	m_2	T_1	1.8	2.6	1.4	1.7	2.9	1.7
					T_2	2.1	3.1	1.2	1.7	2.9	1.8
Mean	1.6	3.1	2.3								

TABLE 2

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
ANTERIOR JOINT GAP--NO POINTERS

	d.f	S.S	M.S	F ratio
A. Trial 1				
between measurements	1	0.041	0.041	0.9
between samples	9	3.201	0.356	
error	9	0.404	0.045	
Total	19	3.646		S.d .44
B. Trial 2				
between measurements	1	0.025	0.025	4.0
between samples	9	5.331	0.592	
error	9	0.05	0.006	
Total	19	5.406		S.d .53
C. Trial 1 + Trial 2				
between T_1 and T_2	1	0.034	0.034	1.0
between measurements	2	0.066	0.033	
between samples	9	8.201	0.911	
error	29	0.841	0.029	
Total	39	9.151		S.d .49

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 3

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
ANTERIOR JOINT GAP--WITH POINTERS

	d.f	S.S	M.S	F ratio
A. Trial 1				
between measurements	1	0.12	0.12	1.6
between samples	9	10.95	1.217	
error	9	0.68	0.076	
Total	19	11.75		S.d .79
B. Trial 2				
between measurements	1	0.012	0.012	0.3
between samples	9	9.95	1.106	
error	9	0.33	0.037	
Total	19	10.29		S.d .73
C. Trial 1 + Trial 2				
between T_1 and T_2	1	0.174	0.174	2.9
between measurements	2	0.132	0.066	
between samples	9	20.265	2.251	
error	29	1.769	0.061	
Total	39	22.34		S.d .74

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 4

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
SUPERIOR JOINT GAP--NO POINTERS

		d.f	S.S	M.S	F ratio
A.	Trial 1				
	between measurements	1	0.00	0.00	0.0
	between samples	9	6.262	0.696	
	error	9	0.170	0.019	
	Total	19	6.432		S.d .58
B.	Trial 2				
	between measurements	1	0.002	0.002	0.03
	between samples	9	7.310	0.812	
	error	9	0.558	0.062	
	Total	19	7.87		S.d .64
C.	Trial 1 + Trial 2				
	between T_1 and T_2	1	0.047	0.047	6.--*
	between measurements	2	0.062	0.001	
	between samples	9	13.056	1.562	
	error	29	0.246	0.008	
	Total	39	14.351		S.d .61

--* significant

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
S.d = standard deviation
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 5

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
SUPERIOR JOINT GAP--WITH POINTERS

		d.f	S.S	M.S	F ratio
A.	Trial 1				
	between measurements	1	0.042	0.042	1.1
	between samples	9	3.852	0.428	
	error	9	0.338	0.037	
	Total	19	4.232		S.d .47
B.	Trial 2				
	between measurements	1	0.072	0.072	2.7
	between samples	9	7.932	0.881	
	error	9	0.258	0.028	
	Total	19	8.262		S.d .67
C.	Trial 1 + Trial 2				
	between T_1 and T_2	1	0.121	0.121	1.7
	between measurements	2	0.114	0.114	
	between samples	9	10.450	1.160	
	error	29	2.044	0.071	
	Total	39	12.615		S.d .57

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 6

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
POSTERIOR JOINT GAP--NO POINTERS

		d.f	S.S	M.S	F ratio
A. Trial 1					
	between measurements	1	0.040	0.040	2.2
	between samples	9	17.620	1.958	
	error	9	0.165	0.018	
	Total	19	17.825		S.d .96
B. Trial 2					
	between measurements	1	0.072	0.072	2.5
	between samples	9	17.450	1.940	
	error	9	0.268	0.029	
	Total	19	17.790		S.d .96
C. Trial 1 + Trial 2					
	between T_1 and T_2	1	0.440	0.440	6.3--*
	between measurements	2	0.112	0.056	
	between samples	9	33.580	3.730	
	error	29	2.036	0.07	
	Total	39			S.d .96

--* significant

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
S.d = standard deviation
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 7

ANALYSIS OF VARIANCE OF RADIOGRAPHIC MEASUREMENTS
POSTERIOR JOINT GAP--WITH POINTERS

	d.f	S.S	M.S	F ratio
A. Trial 1				
between measurements	1	0.144	0.144	1.3
between samples	9	9.892	1.099	
error	9	1.001	0.11	
Total	19	11.037		S.d .76
B. Trial 2				
between measurements	1	0.364	0.364	3.0
between samples	9	11.534	1.282	
error	9	1.131	0.126	
Total	19	13.029		S.d .83
C. Trial 1 + Trial 2				
between T_1 and T_2	1	0.523	0.523	2.3
between measurements	2	0.508	0.254	
between samples	9	21.063	2.34	
error	29	3.004	0.11	
Total	39			S.d .83

d.f = degrees of freedom
S.S = sum of squares
M.S = mean of squares
F ratio becomes significant only when it exceeds the corresponding tabulated value for 5% in the Table of F ratio.

TABLE 8

ANALYSIS OF VARIANCE OF SKULL MEASUREMENTS

		d.f	S.S	M.S	F ratio
A.	Anterior Joint Gap				
	between measurements	1	0.001	0.001	.01
	between samples	9	12.525	1.392	
	error	9	0.584	0.065	
	Total	19	13.110		S.d .83
B.	Superior Joint Gap				
	between measurements	1	0.002	0.002	.03
	between samples	9	7.580	0.842	
	error	19	7.870		S.d .64
C.	Posterior Joint Gap				
	between measurements	1	0.242	0.242	3.2
	between samples	9	13.548	1.505	
	error	9	0.658	0.073	
	Total	19	14.448		S.d .87

TABLE 9

COMBINED ANALYSIS OF ANTERIOR JOINT GAP MEASUREMENTS EMPLOYING AVERAGE VALUES

	d.f	S.S	M.S	F ratio
between T_1 and T_2	2	0.209	0.105	.41
between samples	9	8.159	0.907	
error	18	4.990	0.277	
Total	29	13.358		S.d .68

TABLE 10

CORRELATION OF SKULL MEASUREMENTS WITH RADIOGRAPHIC MEASUREMENTS

	Type of Measurement	Correlation
Ant	1. NP	0.10
	2. WP	.75
Sup	1. NP	.65
	2. WP	.78
Post	1. NP	.78
	2. WP	.77

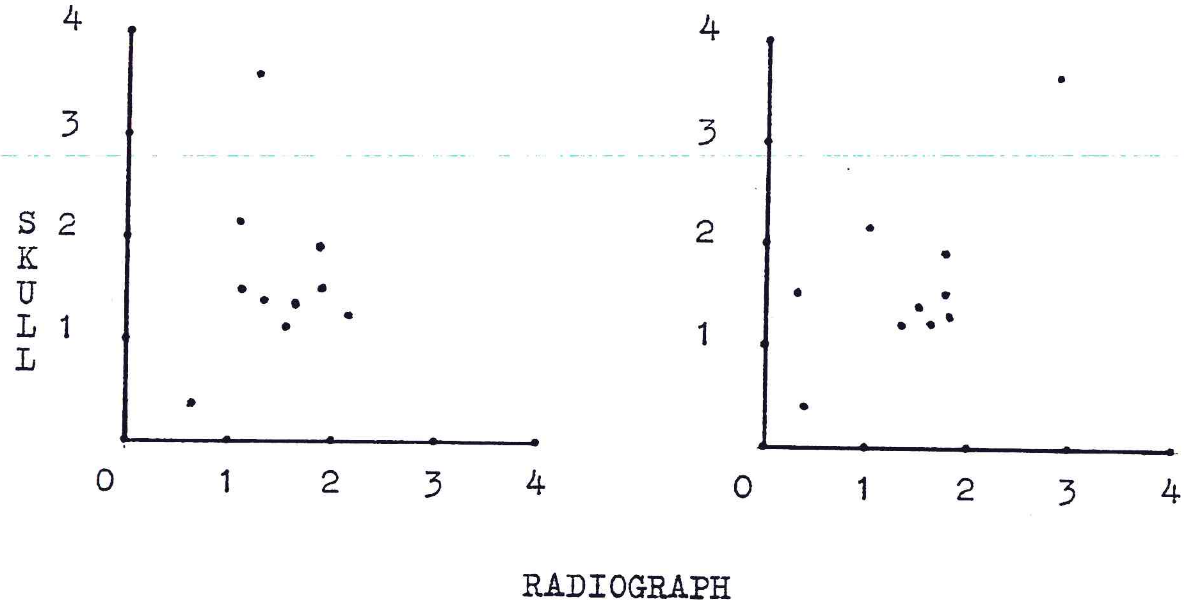
TABLE 11

CORRELATION OF IMAGE DISTORTION TO THE ANGLE THAT THE CENTRAL X-RAY BEAM MAKES WITH THE TRANSVERSE AXIS

	Type of Measurement	Correlation
Ant	1. NP	0
	2. WP	0
Sup	1. NP	.15
	2. WP	.29
Post	1. NP	-.31
	2. WP	-.10

CORRELATION OF SKULL MEASUREMENTS WITH RADIOGRAPHIC MEASUREMENTS

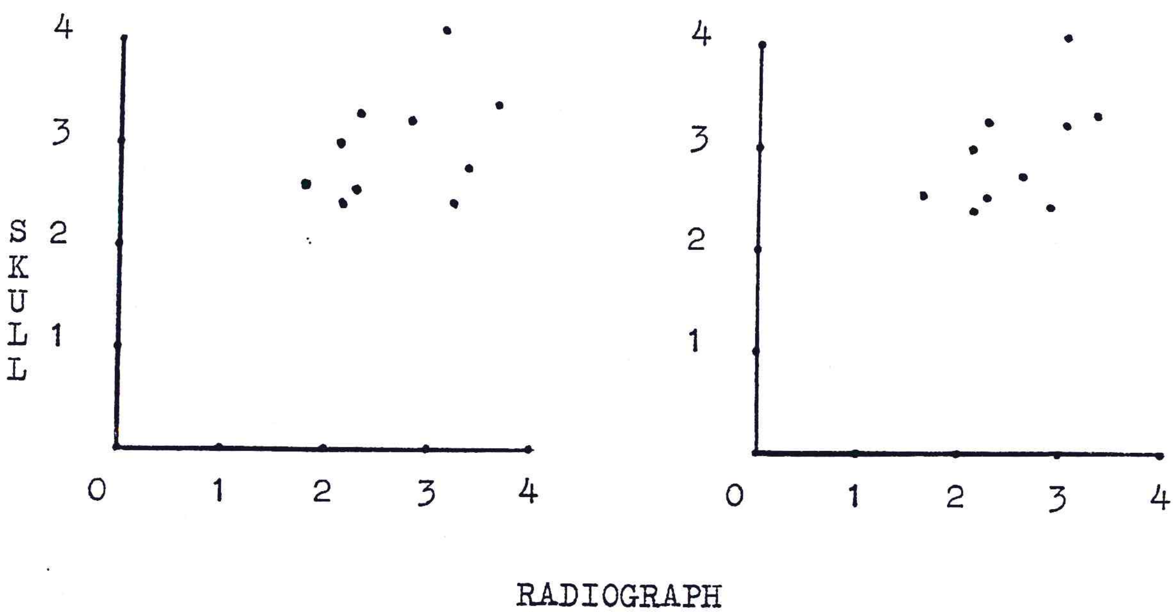
Graph 1 Anterior Joint Gap



(a) No Pointers

(b) With Pointers

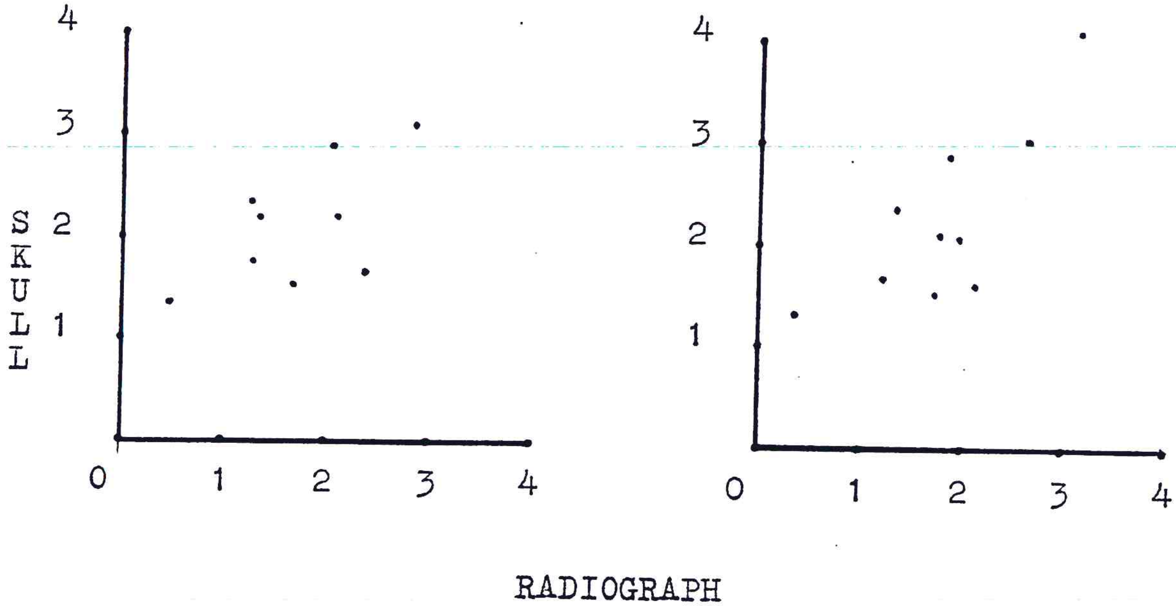
Graph 2 Superior Joint Gap



(a) No Pointers

(b) With Pointers

Graph 3 Posterior Joint Gap



(a) No Pointers

(b) With Pointers

TABLE 12

REPOSITIONING MEASUREMENTS

Skull	Frankfort[1] (T_1-T_2)[3] (in degrees) NP	WP	Vertical Scale[2] (T_1-T_2) (in millimeters) NP	WP	Sagittal Scale (T_1-T_2) (in degrees) NP	WP
566	0.25	0.0	9.0	1.5	0.0	4.5
367	0.5	0.5	4.0	3.0	2.25	4.5
361	2.5	2.75	9.0	0.0	0.0	9.0
344	0.25	0.5	16.0	0.0	0.0	6.75
583	1.25	0.0	7.5	1.5	0.0	4.5
255	2.75	3.25	10.0	3.0	4.5	4.5
340	3.25	0.25	3.0	3.0	0.0	0.0
146	2.75	0.5	6.0	4.0	9.0	9.0
155	1.75	0.75	9.0	0.0	0.0	4.5
576	0.75	0.25	6.0	3.0	4.5	9.0
Totals	16.00	8.75	79.5	19.0	20.3	56.3

[1]Frankfort readings are from the radiographs.

[2]Vertical and sagittal scale readings are from the side protractor assembly.

[3]The T_1 and T_2 differences are obtained by subtracting the average values of the m_1 and m_2 of each trial.

SUMMARY AND CONCLUSIONS

An improved method of lateral oblique radiography of the temporomandibular joint has been presented. The subjects were ten human skulls, each with a full complement of teeth. The equipment included a standard dental x-ray machine in combination with an Updegrave "TMJ Board" to which pointers were added to facilitate more accurate repositioning.

After preparing the left temporomandibular joint with markers, it was radiographed, the joint gaps measured and the angle of the transverse axis of the left condyle determined for each skull. The joint gaps were then measured directly on the radiographs and compared with the measurements of the actual joint gaps on the skull. The site of measurement of the anterior, superior and posterior joint gaps on the skull was at the junction of the middle and lateral thirds of the mesiolateral width of the superior wall of the fossa.

The measuring procedures were standarized, and the technics of No Pointers and With Pointers compared with each other statistically. This study of the reliability of temporomandibular joint gap measurements permitted the following conclusions:

(1) The mean joint gap on the ten skulls were (a) anterior, 1.6, (b) superior, 3.1 and (c) posterior, 2.3 millimeters.

(2) The average angle of the transverse axis to the mid-sagittal plane was 105 degrees; the range was from 99.3 degrees to 114.3 degrees.

(3) It is possible to make accurate measurements of the joint gaps by measuring directly on the radiographs.

(4) The anterior joint gap is more accurately portrayed radiographically when the Updegrave technic is supplemented with pointers.

(5) The superior joint gap is accurately portrayed when either the No Pointer or With Pointers technic is used, although, the NP trials were significantly different from each other.

(6) The posterior joint gap is accurately portrayed when either the NP or WP technic is used, although, the NP trials were significantly different from each other.

(7) There is no correlation of image distortion to the angle that the central x-ray beam makes with the transverse axis of the condyle, as far as the anterior joint gap is concerned.

(8) The superior and posterior joint gap image distortions are correlated to changes in angulation of central x-ray beam.

(9) The optimum angle for radiographing the superior joint gap is different than that for the posterior joint gap.

(10) The use of auxiliary pointers facilitates a more accurate repositioning of the skulls; but, it does not increase the correlation of skull and radiographic measurements, except in the case of the anterior joint gap.

(11) These radiographic findings from human skulls must be repeated in a similar experiment on living persons, in order to show whether or not the Updegrave technic of temporomandibular joint radiography is of significant clinical value.

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