THE RELIABILITY OF REPOSITIONING LIVING HUMAN SUBJECTS FOR SERIAL TEMPOROMANDIBULAR JOINT ROENTGENOGRAPHY USING THE UPDEGRAVE AND A MODIFIED UPDEGRAVE TECHNIQUE

by

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Submitted in partial fulfillment of the requirements
for the Degree of Master of Science

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WESTERN RESERVE UNIVERSITY
June 1964

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ACKNOWLEDGEMENTS

I would like to express my appreciation to the Orthodontic Department of Western Reserve University for the opportunity to make this study, and to Dr. Richard C. Beatty, Chairman, Dr. Sanford Neuger, Research Director, and Dr. Philip Burwasser, Director of Graduate Education, for their help and timely suggestions, and to Dr. Vibeke Nygaard for her special help. To my wife and family, whose sacrifice made this period of my education possible, I express my gratitude.

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INTRODUCTION

The orthodontist deals with a dynamic system involving an intimate association between the masticatory mechanism and the temporomandibular joint. Because mastication, speech, deglutition, and respiration depend, to a large extent, on the movements of the mandible and it's relationships to a stable cranio-facial base, precise knowledge of the functioning of this joint is of importance to all the health specialities. The temporomandibular joint has many functions. One function is to act as a compensatory mechanism of the stomatognathic system. The temporomandibular joint can be affected by changes of occlusion, habit patterns, and many other related incidences in the area. In orthodontic treatment, a thorough diagnosis and a complete survey of treatment results must include consideration of this anatomically complex structure.

Because it is neither practical nor convenient to probe, explore, or expose the articular structures, the only available means for observing the relationship of parts, changes, and movements in the living temporomandibular joint is the roentgenogram. This objective tool has been both used and abused to augment case reports and conclusions.

Amer (1) attempted to discover an adequate roentgenographic technique of the temporomandibular joint and to verify the statements of standard anatomical texts regarding the normal condyle. By studying roentgenograms of living and dry specimens and by orthographic study of cadavers, his investigation showed that there is variation of size and form of the condyle from individual to individual and even between the right and left condyle in the same individual. An undistorted roentgenogram of the temporomandibular joint is impossible due to the superimposition of the petrous portion of the temporal bone (2). The above noted normal variation of structures, compounded with the inaccessibility of the area and the angular variations of any x-ray procedure, emphasize the importance of an adequate x-ray technique.

In a paper titled "A Method of Temporomandibular Joint Roentgenology for Serial or Multiple Records", Donovan (3) concludes the problem under consideration is a difficult one. It is a problem that can be approached from many angles, each with a fair amount of success, but none giving complete satisfaction. Quality of pictures, dissimilar views and angulations, combinations of different techniques, and variations in equipment from a standard x-ray machine to elaborate hospital apparatus combine to give variable results.

Different specialties of medicine and dentistry have differing demands, and attempts at establishing norms through cross sectional data have been unrewarding. Serial data, properly oriented, however, might shed light on the effect that the orthodontist or reconstructive dentist has on the individual patient. Reber (4) points out that the radiographic image of the temporomandibular joint is generated by points in widely separated planes and is not a projection of the center of the joint. Image distortion, caused by angulation of the x-ray source, by variation of the target film distance, and inexact repositioning, can cause misinterpretation of even the best roentgenogram. Image distortion caused by mechanical errors of positioning the patient and the equipment can be minimized by an accurate method of serial repositioning.

The Updegrave technique (5) presents a simplified method of utilizing accessories, at minimal cost, adaptable to the dental office and requiring no special x-ray skill. This technique produces roentgenograms giving excellent functional condyle-fossa relationship. Work done by Baxt (8) has shown this to be a reliable technique in the repositioning of skulls in centric occlusion. By modifying the Updegrave temporomandibular joint board with a set of auxiliary pointers, Baxt has shown more accuracy of repositioning of the same skulls. The reliability of repositioning of living subjects by the Updegrave technique and the Updegrave technique modified by Baxt must be tested to show the value or limitations of these techniques as useful clinical and experimental tools.

PURPOSE

The purpose of this study is:

1) To test the reliability of repositioning living human subjects for serial study, using the Updegrave board.

2) To test the reliability of repositioning living human subjects for serial study, using the Updegrave board, as modified by Baxt.

3) To compare the reliability of repositioning by these two methods.

REVIEW OF THE LITERATURE

There are many techniques and methods of temporomandibular joint radiography described in the past and present literature. A review of this literature emphasizes some universal and, to some extent, unsolved problems which appear in article after article. Because of the location of the joint, proximal to the dense petrous portion of the temporal bone and immediately under the base of the skull, a free presentation of the various parts of the joint is impossible. Shadows of these irregular bony parts mask the lesser more regular profile of the joint area. Most of the techniques project the central x-ray beam in such a way as to avoid the denser more irregular structures. The angulations that are used to avoid superimposition of parts often are oblique to the axis of the joint, and thus they give a somewhat distorted presentation of the joint parts.

Norgaard (9) placed the radiographic approach to the joint into two groups, either profile or enface, and described both groups. For a profile image of the condyle and the glenoid fossa, the oblique lateral transcranial projection is the better approach (9), (10). To this end many angular transcranial techniques have been described.

Berry and Chick (11) grouped the oblique lateral transcranial techniques into pre-auricular, after Gillis

(12), and post-auricular, after Lindblom (13). The terms "pre-auricular" and "post-auricular" refer to the entry point of the central ray on the side of the head away from the joint to be radiographed. By radiographing skulls marked with radio-opaque brass wires, they attempted to show the precise area of the joint depicted in the different approaches. They concluded that the post-auricular technique yielded anatomically more correct outlines than the pre-auricular one. This study also pointed out that the region most frequently used to deduce joint space dimensions and condyle positions is unfortunately the region principally effected by distortion due to angulation change. The use of a positioning method to maintain the degree of distortion at the same level for any one particular patient was suggested.

In this paper no attempt will be made to compare the many techniques but to review several approaches most applicable to the clinical orthodontist. A distinct condyle-fossa profile and a positioning method reliable for serial study will be of prime importance.

Humphreys (14), in 1932, used an angulation technique without any special directional device. He drew an imaginary triangle on a line drawn from the condyle to the mastoid process on the tube side of the head. He directed his x-ray beam about ten degrees downward and ten degrees forward to the opposite joint through the apex of this triangle. The film cassette was in a horizontal position on the side of the joint to be radiographed.

Sproull (15), in 1933, used a twenty-three degree angle board and directed the central ray a measured three inches above the uppermost part of the ear.

In 1935, Gillis (12) with the patient's head tilted against the film cassette had the end of the x-ray tube cut so that when placed against the head and toward the far joint, the central ray was directed at an angle of twenty degrees.

Reisner (16) used a fifteen degree angle board with the mid-sagittal plane of the head parallel to the board. The entry point for the central ray was then measured two inches above and about a half an inch in front of the external auditory meatus.

Lindblom (17), first with a beam director indicator in 1933, then with a transfering bow in 1938, aimed the central ray at a fixed angle to the cassette. The angle was directed to pass as close to the longitudinal axis of the condyle as individual variation would permit. His angulation was fixed fifteen degrees downward from the horizontal plane and fifteen degrees against the frontal plane. Lindblom, citing Schwarz (18), brought out the importance of the upright position of the patient's head in an unstrained position. In these earlier approaches to roentgenography of the temporomandibular joint, most emphasis was placed on the finding of the proper angulation of the central ray to coincide with the axis of the joint and the point of entry on the opposite side of the skull to best project the joint with a minimum of superimposition.

Work done by Amer (1), Craddock (19), Schier (20), and others measuring human skulls to try to determine the angulation of the mandibular condyle revealed variability from one skull to another and even between the right and left sides in the same skull. After utilizing measurements taken on 200 human skulls, Schier reported a new projection angle that would not be fixed for all persons but would be determined individually. He directed the central ray perpendicular to a plane, determined by the high point of the zygoma, gonion, and the prominence formed by the union of the external oblique line and the lower border of the mandible. This plane, called the " planar determinant", was determined by the individual anatomy. With the patient's head upright, the film cassette was positioned contacting these three points and the central ray was directed perpendicular to the film.

Craddock took measurements on twenty six randomly selected mandibles, and he showed that the orientation of the condyles approached closely to bilateral symmetry. In examining over 100 patients, he showed that a standard fifteen degree orientation would coincide with the condylar axis 70% of the time, a fair angle 20% of the time, and a poor angle 10% of the time. He stressed an upright technique and suggested Schier's planar determinant as the only way wide individual variations may be anticipated. He felt that by simple inspection and placing the patient in the proper planes of reference, with the head contacting the cassette, the repositioning of the patient's head for successive identical radiographs would not be difficult to achieve.

Updegrave (6) combined the fifteen degree angle board with the method of Parma (21). He attempted to stimulate roentgenographic investigation by seeking a simplified method which would give consistently satisfactory results with regular dental office equipment and average dental radiographic skills. To the x-ray tube, Dr. Updegrave added a lead diaphragm with a small aperture to reduce the secondary radiation and it's resultant fogging of the film and loss of distinction. He also brought the tube as close to the irrelevant joint as possible to get the maximum distortion of the irrelevant joint. This resulted in less apparent superimposition on the relevant joint. The relevant joint was placed as close to the film cassette as possible to obtain a good view of this joint with minimum distortion.

Updegrave (7) modified his board to maintain a constant position of the tube to the patient and the patient to the board in multiple exposures, and to reposition in subsequent exposures. In following the thinking of Schier against the fixed angle approach, Updegrave, while using the fifteen degree angle board and the tube angulated at a constant ninety degrees, used the anatomy of the patient to determine his sagittal plane relation to the film plane.

In hundreds of examinations at the Temporomandibul-Joint Clinic at Columbia University, Chays and Finkelstein

(22) found the Updegrave technique to be one of the most useful. Because of difficulty with arthritic patients, they modified the Updegrave technique into an upright position. The faults of the Updegrave board that they attempted to remedy were the lack of visibility of the ear plug in position, the length of time required to align the tube, and to provide a more accurate reading for the sagittal plane. The temporomandibular joint roentgenograms they obtained with their modification and with the Updegrave technique were similar.

In 1959, Zech (10) compared the original Updegrave technique with the sagittal plane parallel to the film, with two other projections and found the Updegrave giving the best condyle, fossa, and eminence profile and their interrelationship. Attempts this far had been more in the realm of bettering x-ray technique and providing a means of proper angulation. The position of the patient's head had been, for the most part, lined up by eye. Linear measurements (13), (16), triangular figures (14), or mathmatical formulas (23) were used to determine the interposition of the x-ray tube, the patient's head, and film.

With the acceptance of the cephalometer (24), attention was focused on the desirability of a positioning device to better orient and relate radiographic diagnostic material and techniques. The necessity to provide for the repeated repositioning of an individual, so that accurately comparable roentgenograms could be obtained, was emphasized. Functional records require a means of holding the head in the same plane for multiple exposures and also for serial studies. A recordable method of repositioning the head and film source is necessary. Repositioning devices range from simple angle boards to elaborate head holding equipment.

In 1937, Higley (25) used a cephalostat with calibrated scales to record the upright head position. The patient's head was rotated twenty degrees on the vertical axis and tipped four degrees to the horizontal. These angulations were kept constant for all patients. Measurements taken from 250 skulls by Higley and an additional 2000 measured by Maves (26) showed that there was individual variation, but that Dr. Higley's angulations were proper for the majority of the condyles.

Speidel and Maxon (27) investigated the Higley technique to test the reliability in that an operator could repeat it on a given subject with identical results. The condylar positions were measured from standard horizontal and vertical reference lines projected on to each film from the fixed cassette holder. The right and left joints of thirty-six human subjects were roentgenographed on two separate occasions by the same operator. The condylar positions were measured to the nearest one-tenth of a millimeter and showed deviations in position of the two radiographs of less than two millimeters in 75% of the cases.

Speidel and Goldberg (28) used the same method but with a second operator independently taking the second roentgenograms. They showed deviations of less than three millimeters between operators.

In 1953, Donovan (3) designed a head positioning device which maintains the head in an upright position. He used the back of a Broadbent-Bolton cephalometer to attach his head holding device and tipped the anterior-posterior x-ray tube nineteen degrees caudad and fifteen degrees ventrad. This method was similar to Lindblom's and was designed to make all the mechanical factors constant and to facilitate accurate comparisons of serial radiograms. Ruskin (29) tested Donavan's orienting device and concluded that it permitted accurate duplication of temporomandibular joint radiographs. Ruskin's work was done on a series of ten dry skulls.

Lawther (30) designed and adapted a head positioner to the Broadbent-Bolton cephalometer. The patient's head being tilted so that the porionic axis, instead of being parallel to the central ray, as in cephalometric study, is at an angle ten degrees downward and twelve and one-half degrees forward to the central ray. He positioned and fixed the head in position by a moveable set of ear rods and a nasion rest. This positioner assured accurate repositioning. All patients were placed in the same precise relation to the x-ray source regardless of individual condyle axis. The use of the long target film distance in the cephalometer eliminates distortion and enlargement, and, combined with the large cassette, allows the accurate use of landmarks outside the joint for reference.

Updegrave proposed a simplified technique using standard dental office roentgenographic equipment, combining the angle board with an ear rod and an anatomical determinant for the sagittal plane. With two simple scales, he attempted to record this position and, with simple rods on the board to keep the tube position constant, the central ray was directed at the same spot on the board.

Reber (4) tested to determine the interpretive reliability of the data obtained from the Updegrave board. Reber showed that the linear dimensions obtained from radiographs of the temporomandibular joint are limited in determining morphologic features.

Baxt (8) showed reliability of repositioning of dry human skulls with the Updegrave board. By adding auxiliary pointers to the vertical scale and the tube head, Baxt facilitated a more accurate repositioning of the skulls. He showed it was possible to make accurate measurements of the anterior, superior, and posterior joint gap by measuring directly from x-rays.

The accuracy of the Updegrave technique and board and specifically the accuracy of the repositioning method as well as the modified method of Baxt must be tested on human subjects and the value and limitations made known.

METHOD AND MATERIALS

This experiment was designed to test the extent to which a subject's position could be duplicated in both the Updegrave technique and the Updegrave technique modified by Baxt, hereafter referred to as the modified technique. A comparison of the position of the mandibular condyle, in relation to the glenoid fossa, of the first roentgenogram with it's position in a second and then a third roentgenogram was the method of determining repositional accuracy.

Nine male dental students from the Western Reserve University School of Dentistry were used as subjects. No preference was made to age, physical size, or Angle classification. The only requirement was that each subject present sufficient teeth, natural or artificial, to insure a stable centric occlusion. None were undergoing any orthodontic or dental treatment during the time of the study that might alter the centric occlusion. Subjects were picked more for their dependability and their interest in this study.

All roentgenograms were taken within one month's time. All subjects were radiographed in both the Updegrave and the modified techniques the same number of times. Three trials were run: each trial consisted of two positions, "X" and " X+1", for each method to give twelve roentgenograms for each subject. A total of 108 roentgenograms were used for this study. No two successive pictures were taken on the same subject, and a period of at least forty-eight hours passed between taking of any roentgenograms of successive trials. The subjects were divided into groups of three for convenience in x-ray procedure, and were radiographed in random order. Group appearance was randomized by time availability. Individual order in each group was randomized by drawing numbers before each trial and before radiographing in each position and method within the trial. As many as four roentgenograms of each subject were taken at one time but never more than one in any one trial. Neither method was given preference in order.

The "X" position for all subjects was determined by following the technique of Updegrave. Each subject was asked to rest the left side of his head on the board, with his ear over the ear rod, in a comfortable position. The subject was then assisted to contact the board at three points: the ear rod, the high point of the zygoma, and the angle of the mandible (Fig. 2). This head position was then recorded by raising or lowering the Updegrave protractor rod assembly and by lining up the sagittal scale. The Updegrave readings were determined by lining up the tip of the patient's nose and the sagittal scale by eye (Fig. 1 and 2). In the modified technique, a pointer is added perpendicular to the vertical scale to contact the tip of the nose (Fig. 3 and 4).

To test the accuracy of the recording devices and

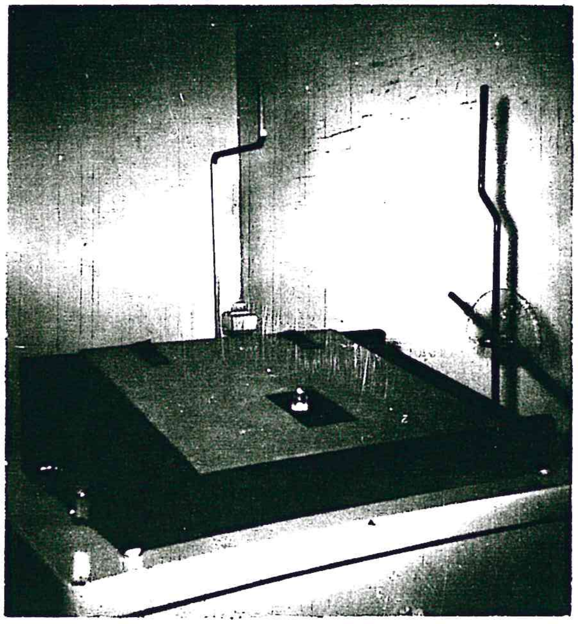


Fig. 1.--Standard Updegrave board.

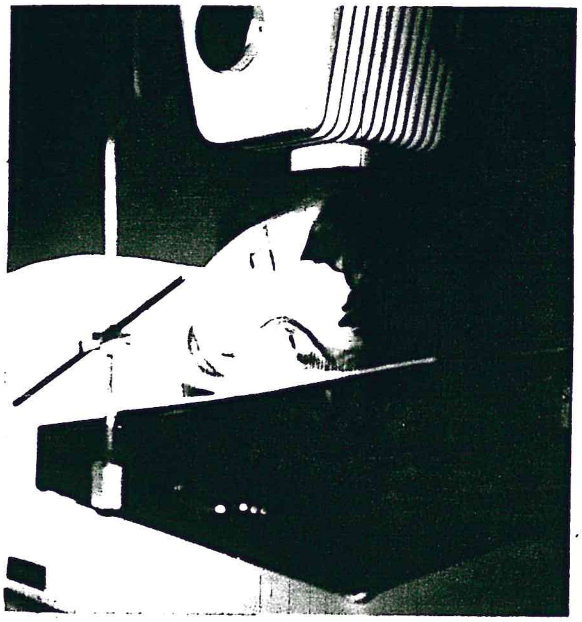


Fig. 2.--Standard Updegrave board with patient in position.

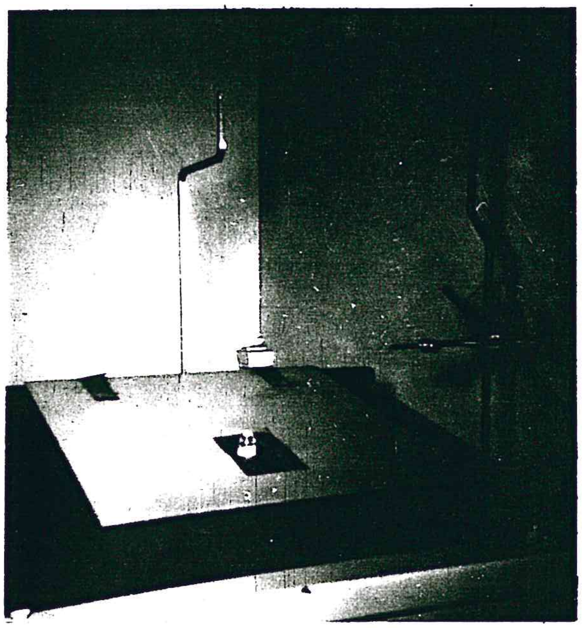


Fig. 3.--Modified Updegrave board.

Fig. 4.--Modified Updegrave board with patient in position.

also to show what effect the alteration of the central ray would have, a position "X+1" was devised. The "X" readings on both the vertical scale and sagittal plane scale were increased by one full measuring unit. This forced the subject into a less comfortable position, in relation to the angle board, and the position was determined largely by the positioning scales. All scale readings were recorded and, on all repositioning trials, the scale values were first set, and then the patient was positioned to conform to them.

In the modified method, the nose was brought into actual contact with the pointer (Fig. 3). In the Updegrave method, the position was sighted by eye (Fig. 2). The Updegrave board has two vertical rods to be used in positioning the x-ray tube, in relation to the board. The tube is positioned by eye, so that one rod bisects the length of the tube casement, and the other bisects the width (Fig. 5). This procedure was followed in the Updegrave technique. In the modified technique, pointers are attached to the outer rim of the diaphragm that replaces the x-ray cone. The pointers are at right angles to each other and bisect the center of the diaphragm. The pointers are adjusted to contact the aligning rods of the board eliminating the aligning by eye of the Updegrave technique (Fig. 6).

The source of x-ray was a standard General Electric 190 dental x-ray machine. The cone was removed and the Updegrave diaphragm was put in place. The standard Updegrave board was used for the Updegrave method. The modifications

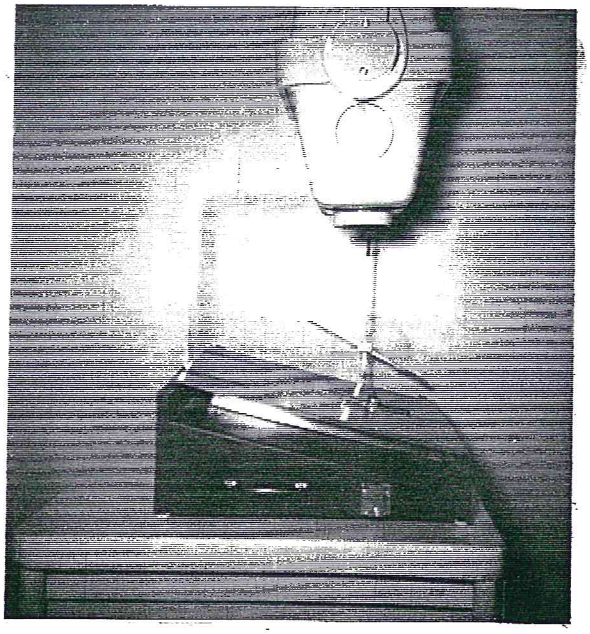


Fig. 5.--Tube positioned by the Updegrave aligning rods.

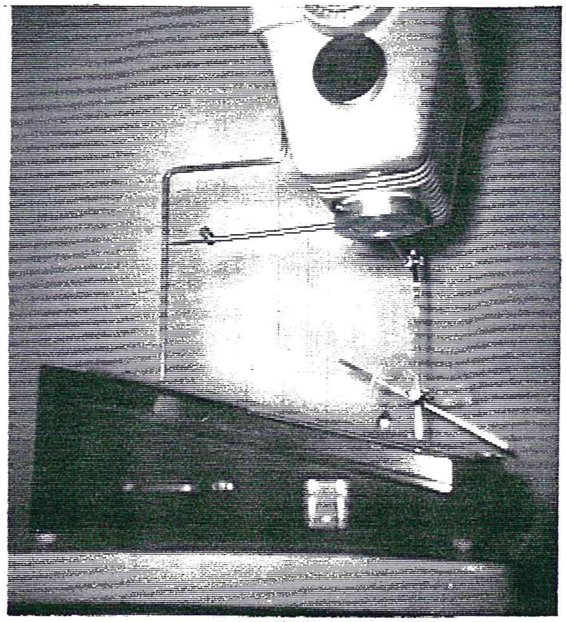


Fig. 6.--Tube positioned with the Baxt pointers contacting the aligning rods.

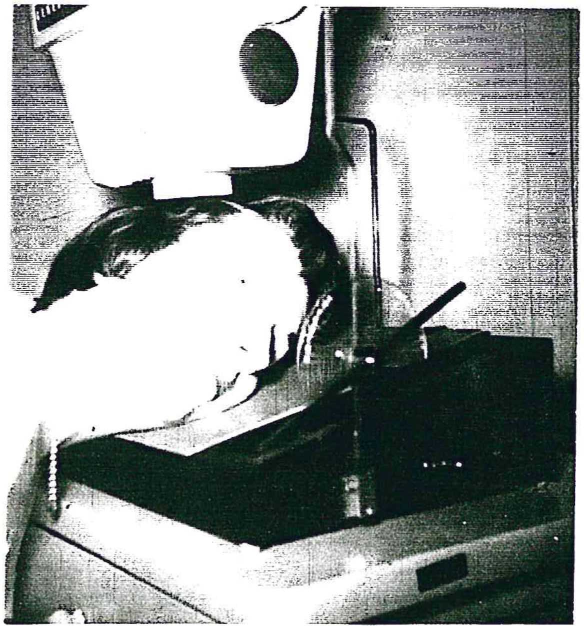


Fig. 7.--The Updegrave technique.

Fig. 8.--The modified technique.

of Baxt were added to the standard board in the modified method. Kodak Blue Brand film in an 8 x 10 cassette, with an intensifying screen, was used allowing six pictures to be taken on each film. One-third of a second exposure time at 10 M.A. and 65 K.V. was used for all subjects, regardless of size. This posed some range of darkness but did not effect the interpretation of the film. Only the left joint was roentgenographed, and the patient was always asked to close in centric occlusion. Centric occlusion was used because it is the most reliable position of the condyle in the glenoid fossa (2), (31). It has been shown that condyle to fossa relationship does not change with light biting force as opposed to clenching force (30). So all subjects were asked to bite firmly, letting occlusal anatomy determine the mandibular position.

All measurements were made directly on the developed roentgenogram. The accuracy of direct measurements on the roentgenogram without tracing outlines and without calculation from other values taken from the film is brought out by Bjork and Solow (32). To show the relation of the condyle to the fossa, the joint gap area was measured to the nearest one-tenth of a millimeter with a fine pointed Boley gauge. The anterior, posterior, and superior joint gap were all measured. To determine the area to be measured, the method of Craddock (19) was modified to use the wire assembly orienting lines of the Updegrave board. A line was first drawn from the high point of the glenoid fossa perpendicular to the horizontal orienting line. Two lines were drawn at 45 degree angles from the horizontal orienting line. Line "A" was made to pass through the narrowest portion of the anterior joint gap, and to intersect the horizontal orienting line at a 45 degree angle, and to cross line "B". Line "C" was made to pass through the point of intersection of line "A" and " B" and to intersect the horizontal orienting line at an angle of 45 degrees.

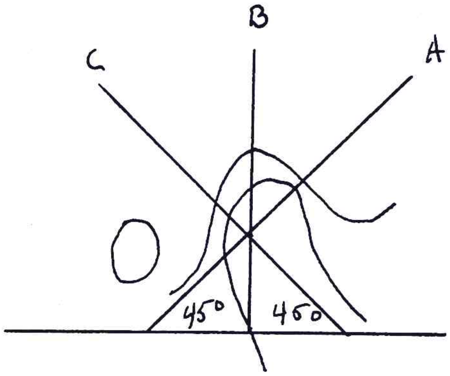


Fig. 9.--The anterior, posterior, and superior joint gap determinant.

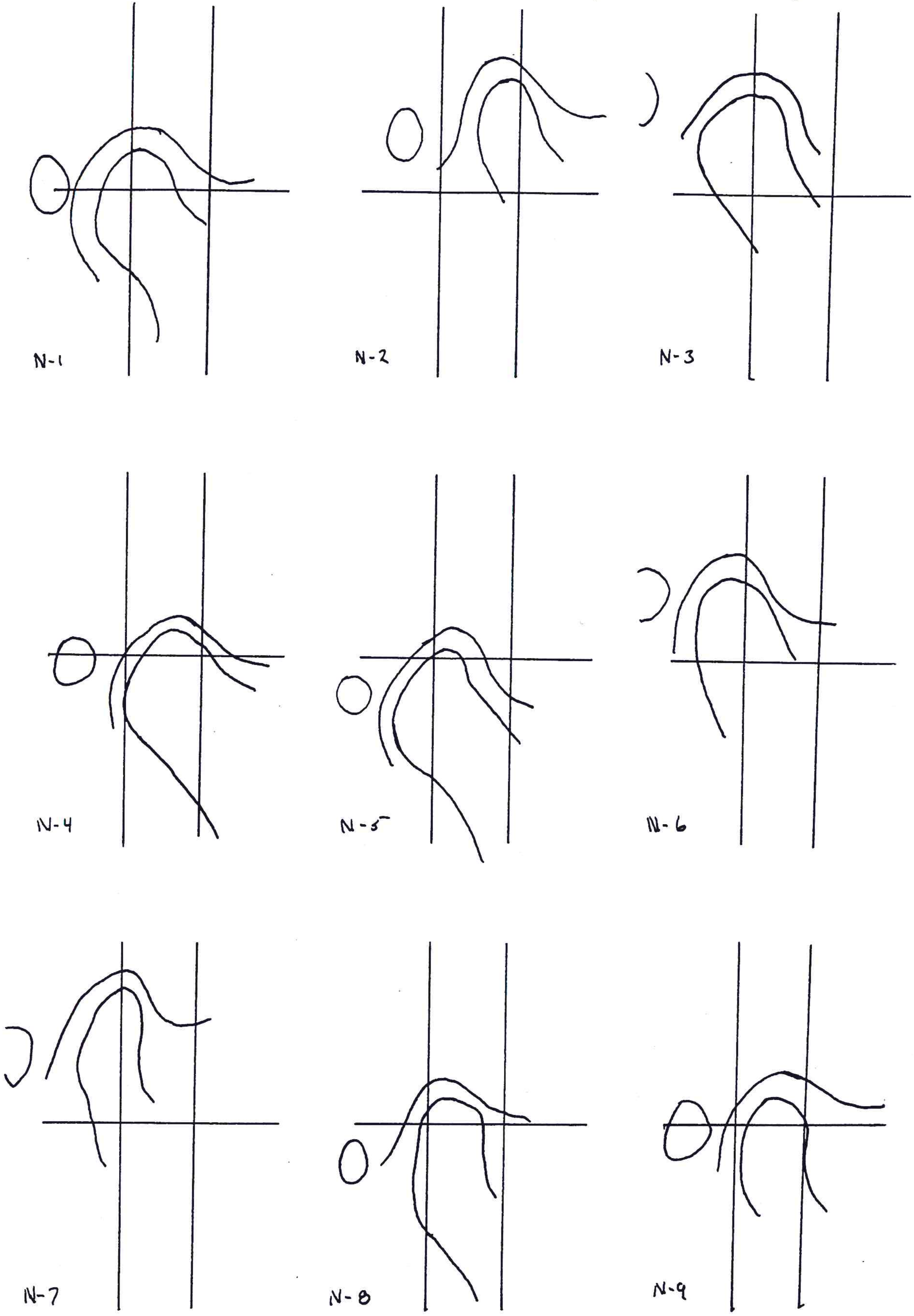
The degree of accuracy with which the subjects were repositioned for their second and third roentgenograms in both methods and both positions in each method was determined by comparing corresponding measurements. A statistical analysis of the data was applied according to accepted procedures.

DISCUSSION

The reliability of repositioning for serial study is summed up in Table 9. Using the modified Updegrave technique (M_2) in position one (P_1), joint gap measurements in repositioned roentgenograms were accurate to ± .124 millimeters. The Updegrave technique (M_1) was accurate to ± .231 millimeters. No significant difference in repositioning was noted in P_1 and P_2 of the Updegrave technique or in P_2 of the modified technique. The combination of the angle board contacting the three anatomically determined landmarks as prescribed by Updegrave and the auxiliary pointers added to the Updegrave board by Baxt produced more accurate repositioning than the standard Updegrave board alone.

The joint gap area was altered by change of position, as in P_1 and P_2, but due to the large inherent variability of the subjects, no significant changes could be applied to all subjects attributed solely to the positional change. That is, gap area in one joint might be larger in P_1, and in another joint, the gap area might be larger in P_2. Due to the large variance from subject to subject (Fig. 10), the changes in gap area attributed to positional change were not significant. This pointed to a well established view --- that there is great anatomic variance among individuals, and great difficulty arises if one tries to relate one individ-

Fig. 10 -- Inherent Variability of Joint Gap.



ual to another.

The effect of change of position within one subject was significant in both methods. Method two, only, showed a significant difference of accuracy of repositioning, directly attributed to position across all skulls. For all the combinations of methods and positions, no one gap area, anterior, superior, or posterior, showed to be any more accurate than the other, in terms of analytical error.

FINDINGS

The data was recorded in three separate tables, headed Anterior (Z_1), Posterior (Z_2), and Superior (Z_3) Joint Gap. (Tables I, 2, 3). Method one (M_1) designates the Updegrave method; method two (M_2) designates the modified method; position one (P1) corresponds to the X reading on the scales; position two (P_2) corresponds to the X+1 readings. Subjects were numbered N_1 through N_9.

The data was first assembled and set up in a table for analysis of variance. There were five variables to be considered:

1) Z, the gap being measured
2) M, the method used
3) N, the individual subjects
4) P, the position of the subject
5) C, the three trials made under each set of conditions

After considerable difficulty in a preliminary analysis of variance, it was decided to treat Z as a variable nested within N. This means that for each subject, N, the gap readings will be a unique function of that particular subject. Thus, for a subject with a large joint area, all gap readings will be large, and on a subject with a small joint area, all gap readings will be small. C is a nested variable within

ZMPN since it is a unique function of these four variables.

An analysis of variance was made and the various effects were tested against the analytical error, C(ZMPN). When this was done, all the higher order interactions containing N proved to be significant. This pointed out that this study contained essentially two types of error; the analytical error, and the error that results from the inherent variability of the individual subjects. Since each subject is unique, there is an error term which arises from the particular construction and configuration of the individual skull and joint area. This error term was designated as PMZ(N).

A second analysis of variance was performed testing the effects against PMZ(N) for significance. Knowing the analytical error and the total variance, the magnitude of the individual variances were found using the components of variances. For example, knowing the value of $\sigma^2 C(ZMPN)$ and the value of $\sigma^2 C(ZMPN) + C\sigma^2 PMZ(N)$, the magnitude of $\sigma^2 PMZ(N)$ can be found.

The final procedure was to determine the magnitude of the analytical errors as a function of the variables Z, P, and M. The analytical error C(N) was first determined for each set ZPM. These values were Cochran tested by dividing the highest error variance in the group being tested by the sum of the error variance for the group. This ratio was then compared with a critical ratio from a Cochran table to determine if the errors were homogeneous.

The error terms were first tested for homogeneity across Z. This was done because it was felt that since Z was a nested variable, these error terms might prove to be homogeneous. The error terms were then tested across P and finally across M. A table of error variances and a table for the standard errors was then constructed.

The results of the analysis of variance, when testing against the analytical error, are found in Table 4. The significant effects were N, Z(N), MN, MZ(N), NP, PZ(N), PMZN, and MPN. The results of the analysis of variance for a test against skull error are contained in Table 5. Here the significant effects were PZ(N), NP, Z(N), and N.

The magnitude of the individual variances of individual effect that are significant when compared to the analytical error are found in Table 6. This table also contains the effects as a percent of the analytical error.

Table 7 contains the values for the variances of each ZPM set. Table 8 contains the pooled values for these variances. Table 9 gives the standard errors that correspond to these variances.

TABLE I

ANTERIOR JOINT GAP (Z_1)

M_1 P_1

N	T_1	T_2	T_3
1	2.9	3.0	3.0
2	1.3	1.2	1.4
3	2.4	2.4	2.2
4	2.4	2.3	2.6
5	4.3	4.6	4.5
6	1.6	1.9	1.5
7	3.7	3.0	3.6
8	1.6	1.4	1.5
9	3.6	3.7	3.7

M_2 P_1

N	T_1	T_2	T_3
1	3.3	3.2	3.3
2	0.9	1.0	1.4
3	2.5	2.6	2.4
4	2.0	2.1	2.3
5	4.3	4.5	4.2
6	1.4	1.4	1.6
7	3.0	3.2	3.4
8	1.5	1.7	1.7
9	3.9	3.8	3,7

M_1 P_2

N	T_1	T_2	T_3
1	3.9	2.7	3.4
2	0.7	0.7	0.4
3	2.8	2.4	2.7
4	2.0	2.5	2.2
5	5.5	5.6	5.2
6	1.3	1.5	1.0
7	3.3	2.5	3.4
8	1.3	1.2	1.3
9	3.5	4.0	4.2

M_2 P_2

N	T_1	T_2	T_3
1	2.4	3.0	3.4
2	0.4	0.4	0.5
3	3.0	2.4	3.0
4	1.6	1.9	2.0
5	4.4	5.0	4.7
6	1.8	1.4	1.3
7	3.0	2.8	3.0
8	1.5	1.4	1.5
9	3.7	4.0	4.1

TABLE 2

POSTERIOR JOINT GAP (Z_2)

M_1 P_1

N	T_1	T_2	T_3
1	2.4	2.3	2.6
2	3.4	3.2	3.0
3	3.2	3.4	3.3
4	2.5	2.3	2.0
5	1.8	2.0	1.8
6	2.0	2.4	2.5
7	2.8	2.6	2.5
8	2.0	1.9	2.3
9	3.3	3.2	3.5

M_2 P_1

N	T_1	T_2	T_3
1	2.4	2.4	2.5
2	2.7	2.8	2.5
3	3.4	3.4	3.4
4	2.4	2.4	2.3
5	2.4	2.3	2.3
6	2.3	2.0	2.1
7	2.9	2.7	2.9
8	2.3	2.4	2.4
9	3.2	3.2	3.1

M_1 P_2

N	T_1	T_2	T_3
1	2.9	2.9	2.5
2	3.0	2.8	2.7
3	3.2	3.4	3.7
4	1.7	1.5	1.8
5	1.9	1.9	2.1
6	2.8	2.1	2.4
7	2.8	2.5	3.0
8	2.2	2.2	2.0
9	3.6	3.3	3.2

M_2 P_2

N	T_1	T_2	T_3
1	2.6	2.5	2.6
2	2.5	2.3	2.4
3	2.7	3.2	3.2
4	2.2	1.5	1.2
5	1.7	1.8	1.9
6	2.4	2.5	2.4
7	2.9	3.0	3.2
8	2.2	2.3	2.2
9	3.2	3.2	3.4

TABLE 3

SUPERIOR JOINT GAP (Z_3)

M_1 P_1

N	T_1	T_2	T_3
1	2.3	2.6	2.6
2	3.5	3.2	3.2
3	3.4	2.9	3.5
4	3.0	3.2	3.2
5	2.7	2.4	2.8
6	4.2	4.4	4.7
7	3.4	3.5	3.9
8	3.2	3.0	2.8
9	4.4	3.8	4.5

M_2 P_2

N	T_1	T_2	T_3
1	2.8	3.0	2.9
2	2.9	3.0	3.2
3	3.4	3.2	3.5
4	2.6	2.7	2.8
5	2.6	2.4	2.5
6	4.1	4.3	4.4
7	3.5	3.3	3.5
8	3.0	3.1	2.9
9	4.2	4.0	4.2

M_1 P_2

N	T_1	T_2	T_3
1	2.8	2.7	3.2
2	2.5	2.0	2.4
3	3.3	3.5	3.6
4	2.5	2.7	2.5
5	3.7	3.3	3.8
6	4.3	4.4	3.7
7	3.0	2.5	3.2
8	2.4	2.2	2.5
9	4.2	4.3	4.3

M_2 P_2

N	T_1	T_2	T_3
1	2.6	2.8	2.8
2	1.5	1.2	1.5
3	3.4	3.1	3.4
4	2.2	2.2	2.1
5	4.7	4.1	4.2
6	4.4	4.3	4.5
7	3.4	3.2	3.5
8	2.6	2.6	2.7
9	4.4	4.5	4.4

TABLE 4

ANALYSIS OF VARIANCE (ANALYTICAL ERROR) ANOVA

S.V.	S.S.	D.F.	M.S.	F.	F. CRIT.	
N	98.313	8	12.289	278.6	1.98	Sig.
Z(N)	148.555	18	8.253	187.0	1.62	Sig.
M	.203	1	.203	.742	5.32	N.S.
MN	2.189	8	.2736	6.20	1.98	Sig.
MZ(N)	2.151	18	.1195	2.71	1.62	Sig.
P	.546	1	.546	.377	5.32	N.S.
NP	11.589	8	1.4486	32.84	1.98	Sig.
PZ(N)	7.238	18	.4021	9.12	1.62	Sig.
MP	.033	1	.033	.219	5.32	N.S.
MPN	1.204	8	.1505	3.41	1.98	Sig.
PMZ(N)	1.871	18	.1039	2.36	1.62	Sig.
C(ZMPN)	9.527	216	.04411	----	----	---
	283.419	323				

Sig. -- significant

N.S. -- not significant

Significant effects

N, Z(N), MN, MZ(N), NP, PZ(N), PMZ(N), MPN

Tested against analytical error

S.V. -- source of variance
S.S. -- sum of squares
D.F. -- degrees of freedom
M.S. -- mean of squares
F. -- F test
F. CRIT. -- F. critical

TABLE 5

ANALYSIS OF VARIANCE (SKULL ERROR) ANOVA

S.V.	S.S.	D.F.	M.S.	F.	F. CRIT.
N	98.313	8	12.289	82.5	2.10 Sig.
Z(N)	148.555	18	8.253	55.4	1.75 Sig.
M	.203	1	.203	1.61	4.08 N.S.
MN	2.189	8	.2736	2.17	2.18 N.S.
MZ(N)	2.151	18	.1195	1.01	1.99 N.S.
P	.546	1	.546	.377	5.32 N.S.
NP	11.589	8	1.4486	12.25	2.32 Sig.
PZ(N)	7.238	18	.4021	3.40	1.99 Sig.
MP	.033	1	.033	.279	4.23 N.S.
MPN	1.204	8	.1505	1.45	2.51 N.S.
PMZ(N)	1.871	18	.1039	---	---
Total	273.892	107			

Sig. -- significant

N.S. -- not significant

Significant effects

PZ(N), NP, Z(N), N

Tested against highest order interaction

S.V. -- source of variance
S.S. -- sum of squares
D.F. -- degrees of freedom
M.S. -- mean of squares
F. -- F test
F. CRIT. -- F. critical

TABLE 6

MAGNITUDE OF VARIANCES

		Variance	% σ^2C(ZMPN)
Analytical Error	σ^2C(ZMPN)	.0441	100.0
Skull Error	σ^2PMZ(N)	.0199	45.1
	σ^2MPN	.0104	23.6
	σ^2MP	-----	-----
	σ^2PZ(N)	.0597	135.4
	σ^2NP	.0725	164.4
	σ^2P	-----	-----
	σ^2MZ(N)	.0127	28.8
	σ^2MN	.0123	27.9
	σ^2M	-----	-----
	σ^2Z(N)	.651	1476.
	σ^2N	.329	746.

TABLE 7

TABLE OF VARIANCES FOR EACH ZMP SET

	Z_1	Z_2	Z_3
M_1P_1	.0306	.0344	.0594
M_1P_2	.1094	.0467	.0606
M_2P_1	.0228	.0083	.0150
M_2P_2	.0711	.0461	.0244

TABLE 8

POOLED VARIANCES (ANALYTICAL ERROR)

	M_1	M_2
P_1	.0536	.0154
P_2	.0536	.0536

TABLE 9

STANDARD ERRORS (ANALYTICAL)

	M_1	M_2
P_1	.231	.124
P_2	.231	.231

SUMMARY AND CONCLUSIONS

An attempt was made to evaluate the accuracy of repositioning for serial study of:

1) The Updegrave technique of temporomandibular joint radiography using the Updegrave board and positioning devices.
2) The Updegrave technique of temporomandibular joint radiography using the Updegrave board as modified by Baxt with a set of auxiliary pointers for positioning.

A comparison of the accuracy of each of these two methods was made.

This investigation was performed on a group of nine dental students, who were radiographed in three repositioned trials, in two different positions in each of the above methods. A total of 108 roentgenograms were measured directly from the film, and the measurements were compared by accepted statistical procedures.

An interpretation of the evidence presented indicated accuracy within two-tenths of a millimeter in all positions, and accuracy within one-tenth of a millimeter in the modified Updegrave technique in position one.

The significant effects were:

1) PZ(N), the interaction of the gap reading with

skull position for individual skulls.

2) NP, the interaction of skulls and positions.

3) Z(N), the variability of the three gap readings for different skulls.

4) The variability among skulls.

The skull error is of the same order of magnitude as the analytical error and contributes significantly to the total error.

The two most significant effects in terms of variance are Z(N) and N.

The standard analytical error for method two in position one (M_2P_1) is significantly smaller than the error in all other positions and methods.

For any combination of method and position, the three gap readings can be considered to produce the same analytical error.

A change of head position on the board results in a change of the measured gap area in all skulls. However, due to the variability between skulls, significant changes directly due to position change could be shown only for individual skulls. Joint gap measurements varied among skulls, and all three areas varied independently with individual subjects. No one gap area, anterior, superior, or posterior, showed any greater degree of accuracy than the others. Accuracy of repositioning was not significantly effected by position except in M_2P_1. The addition of auxiliary pointers increased the repositional accuracy of the Updegrave technique of temporomandibular joint roentgenography.

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