Accurate Depth of Cut in Temporomandibular Joint Laminagraphs

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Although many dental practitioners and researchers have focused attention on properly-functioning occlusal relationships and an understanding of the temporomandibular joint with associated structures of the temporomandibular joint dysfunction, the need for better methods of establishing a differential diagnosis in treatment is recognized. Accurate radiographic visualization of the temporomandibular joint would be beneficial. However, quality radiographs by conventional means are complicated by the fact that the lateral radiographic image includes the dense petrous portion of the temporal bone. In frontal views the articular eminence, the root of the zygoma, and the floor of the orbit are also included in the radiograph. All of these structures produce a clouding effect which makes radiographic interpretation difficult or impossible.

The potential to overcome these and other shortcomings of conventional radiography occurred with the development of the laminagraph (also known as the tomograph, sectograph and planigraph). In this technique special X-ray equipment is used to make a radiographic "slice" through an anatomical part at a predetermined level to visualize anatomical structures that are obscured by overlying structures. In lateral temporomandibular joint laminagraphy the radiographic "slice" is made through the condyle and fossa between the medial and lateral poles of the condyle.

Depth of cut determinations can sometimes prove unreliable. In many instances a "shotgun" approach must be used in which several radiographs at different depth of cut settings are taken to obtain a clinically acceptable laminagraph. Different investigations have improved the techniques of laminagraphy. Some recommended rotating the head a standard angulation.[1-4,7] Others suggested individualizing the amount of head rotation to the patient.[8-10] In a study done by Wilson,[9] a preliminary submentovertex (basilar) radiograph to determine precise individual condylar angulations and a more accurate depth of cut was utilized. He found a wide range of condylar angulations and a small percentage of quality laminagraphs which could be obtained using standard condylar angulations. This submentovertex analysis represents a significant improvement in temporomandibular joint laminagraphy.

After scrutiny of the laminagraphic machine, it was decided that three factors in the submentovertex analysis could possibly produce significant error and, therefore, should be examined:

1. Importance of magnification distortion of the radiograph.
2. Importance of the midsagittal plane as determined by the machine.
3. Effect of head rotation on depth of cut determination.

METHODS AND MATERIALS

The machine used in this study was the Quint X-Ray Sectograph. This sectograph has the capability to produce both stationary radiographs such as frontal, lateral and basilar cephalograms, and also laminagraphs, which are made with the anode and film in motion.

The first machine factor which required examination was magnification. Determination of the magnification value was accomplished by comparison of actual measurements with radiographic measurements of the same structures. The differences between the actual and radiographic measurements were calculated and it was discovered that the magnification distortion inherent in the Quint Sectograph was either identical to, or extremely close to the magnification values listed in several charts throughout the literature. The chart shown in Thurow's text[5] was chosen because of its applicability in both conventional and laminagraphic radiography. For the remainder of the study, all magnification correction factors were taken directly from this chart.

In investigating the second factor, it was the contention of the authors that all measurements should be taken from machine and not anatomical landmarks. Before any radiographs were made, a method of accurately locating the center of the headholder on the radiographs had to be derived. To accomplish this, the headholder was rotated to the 90° setting, as it would be for a frontal cephalogram. The anode and film holder were placed in the center static position. A plumb line was dropped from the center of the headholder rotation point. For adjustment purposes the sectograph used has a light in the anode apparatus. In a darkened room this light throws a beam through the collimator and onto the cassette holder, giving a visual facsimile of the X-ray beam. This light was used to cast a shadow of the plumb line onto the cassette holder. A straight piece of .030″ wire was carefully centered over this shadow and taped securely onto the cassette holder. All radiographs taken with this wire in place show a definite radiopaque line which represented the center of the headholder. This line delineated the midsagittal plane as determined by the machine and could be used as the zero point from which future depth of cut measurements could be made.

The third factor to be considered was the effect of head rotation on depth of cut determination. As the patient's head is rotated in the headholder, the condyle or any structure will follow the arc of a circle, the center of which corresponds to the center of the headholder. The depth of cut will be located on this arc, measured to the machine midsagittal plane. Since a curve is being related to a straight line (midsagittal plane), the target is constantly changing distances from the midsagittal plane as the head is rotated. The target may be nearer or farther from the zero plane after the head is rotated than before.

Submentovertex radiographs of 51 adult live subjects were used in this study. All exposures were made on Kodak X-Omat L film (8″ × 10″). The output of the sectograph was measured to be 140 mR at an exposure setting of 200 MA, 90 KVP at ⅔ second.

The basilar cephalograms were traced on acetate (Fig. 1). A line connecting the center of both ear rods was drawn. This line (A – B) is the transear rod axis and for convenience purposes is referred to as TEA. The radiopaque line representing the machine midsagittal plane was traced (line C – D). The intersection of AB with CD is point O.

The long axes of both right and

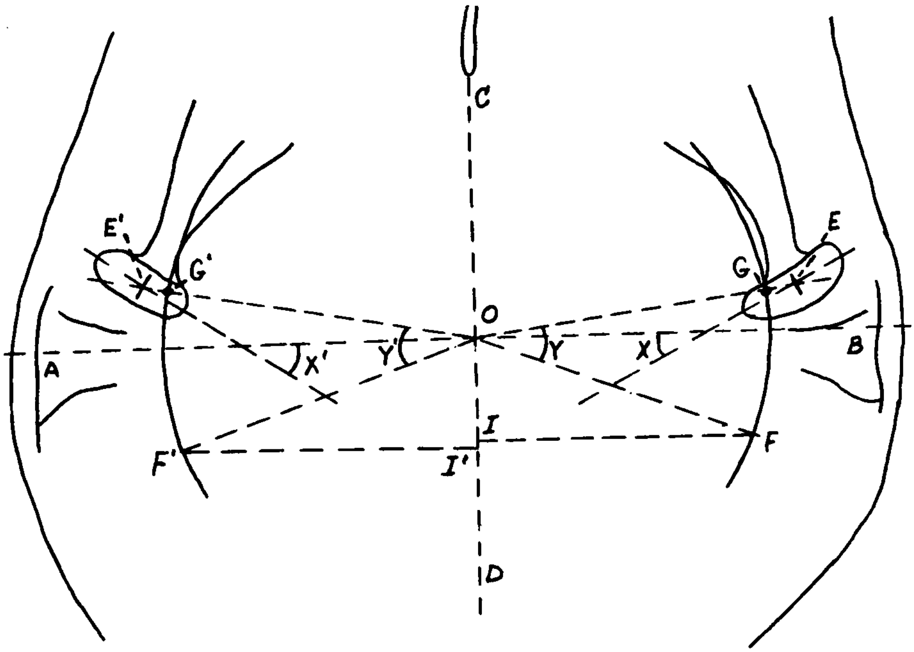

Fig. 1 Tracing of basilar cephalogram showing the points identified in the text and the line. and arcs drawn to determine the depth of cut for each condyle. Transear rod axis (A-B), machine midsagittal plane (C-D), intersection of A-B and C-D (O), centers of condyles E and E', corrected centers of condyles (G and G'), condylar angles (X and X'), position of condyles when head is rotated in the headholder (F and F'), angle of head rotation (Y and Y').

left condyles were drawn from medial pole to lateral pole through the geometric center of the condyle and extended until they intersected with the midsagittal line. The acute angle formed at the intersection with the TEA line is the condylar angle (X and X′). The geometric center of each condyle was determined by inspection (E and E′). Whenever condylar morphology prevented a line connecting the poles from passing through the geometric center of the condyle, as in kidney-shaped condyles, a line was drawn parallel to the anterior surface of the condyle through the geometric center. Condylar angulations for right and left condyles were recorded.

Lines were drawn from the intersection (O) of the lines A-B and C-D to the centers of the condyles (E and E′). The distances were measured and corrected using the values in Thurow's chart and marked on the respective lines EO and E′O as points G and G′. Arcs were then scribed using the rotation point of the headholder (point O) as centers, and the distances from point O to the corrected condylar center as their radii (G and G′). These arcs GF and G′F′ simulate the movement of the condyles as the head is rotated so that the central X-ray beam will pass parallel to the condylar axis. Angles EOF and E′OF′ (Y and Y′) represent the amount of head rotation and are equal to the condylar angle readings. Point F and F′ are the intersections of the arcs and lines OF and OF′ and locate the exact position of the condyle when the head is rotated in the headholder. The lines FI and F′I′ drawn perpendicular to C′D from F and F′ represent the new depth of cut measurements after the head is correctly positioned for a lateral laminagraph (Fig. 1).

The depth of cut for a lateral laminagraphic exposure was determined for each condyle, first using the method described in this study, and then by the method described by Williamson and Wilson.[8,9]

Findings

The range for right condylar angulation was −22° to 45° with a mean of 24.08° (s.e. 1.66). The range of left condylar angulations was −30° to 47° with a mean of 24.53° (s.e. 1.32). No statistical difference in right and left angulation was found.

The two methods of midline determination were compared. The mean midline difference was −.81 mm and the standard error was .27. This is highly significant ($P < .01$) and indicated a tendency of the machine midline to lie to the patient's left of the transporionic axis midline.

The difference between the two methods in depth of cut was determined for each side. The mean difference for the right side was .17 mm (s.e. 0.44), while the mean difference for the left was 1.52 mm (s.e. 0.41). The difference between the right and left differences in depth of cuts was significant ($P < .02$) and a positive correlation ($P < .01$) existed between right and left depths of cut.

Correlation coefficients for right and left paired data, the right condylar angulation, and right difference in depth of cut and the same measurements on the left were calculated. The right condylar angulation to right difference in depth of cut correlation coefficient was .37, and the left was .55. Both were significant ($P < .01$). This indicates a tendency for the difference in depth of cut to increase as the condylar angulation increases.

It was noticed that the horizontal position of the condyle (TEA to condyle) might also have an effect on depth of cut. It was decided to evaluate the combined effect of TEA distance and the angulation of the condyle upon depth of cut. The sample was divided into three groups: those with condylar angulations of 30° or more, those with angulations of 20° − 29°, and those below 20°. These were then further divided according to TEA to condylar distance: greater than 10 mm, 4 − 10 mm, and less than 4 mm. The average difference in depth of cut for each of the nine possible combinations was calculated (Table I).

Combinations of angles greater than 29°, and TEA to condylar distances of less than 4 mm have a definite effect on depths of cut as determined by the two methods. The mean difference in depth of cut was 4.26 mm with this combination. Likewise, condylar angulations smaller than 20°, but with TEA to condylar distances of less than 10 mm, produce a large mean difference in depth of cut of −3.5 mm.

Intermediate (20° − 29°) condylar angles and condyle to TEA measure-

TABLE I

Mean difference in depth of cut in millimeters and standard error of the mean for various condylar angles and TEA to condylar distances.

Condylar Angulation (deg.)	*TEA to Condylar Distances* (mm)	*Mean Difference In Depth of Cut* $\bar{X}$	S.E.
	10	—.97	.80
29°	4 - 10	3.21	.83
	4	4.26	.55
	10	—2.52	.74
20 - 29°	4 - 10	.39	.54
	4	2.22	.36
	10	—3.50	.45
20°	4 - 10	—1.75	.45
	4	.46	.64

ments (4 – 10 mm) combine to produce a small difference in depth of cut (.39 mm). As similar extremes of either measurement are combined (i.e., high angle, high TEA distance or low angle, low TEA distance), the effect of the difference of the depth of cut is reduced.

Discussion

In gathering the material for this study an attempt was made to include condyles with unusually high or low condylar angulations. This was done because the differences between the two submentovertex analyses would be more apparent if the condylar angulations were extreme. Because of this nonrandom sampling the mean condylar angulations for both right and left condyles were higher than recorded in studies in the past.[19] It should be noted that the means were higher than the 15° standard angulation recommended by Ricketts[3] and Updegrave.[6] They were also higher than those found on skeletal material by Wilson.[9] Only Shore,[4] who recommended a standard 25° angulation, approximated the mean condylar angulations found in this study.

Another factor which could have contributed to these differences is the methods used to assign condylar angulations. The very wide range of condylar shapes as seen in the basilar view make consistent assignment of condylar angulations very difficult. The authors tracing the same condyle often differed by as much as 5°, and it was because of this inconsistency that a uniform method of assigning condylar angulations was described. Perhaps the difference in methods of condylar angulation assignment contributed to the disparity in the mean condylar angulations of this sample with studies of the past.

If one used a standard angulation of 15° or 20° with a ±3° as the range permitted for accurate condylar angulation assignment, only 22.12 percent of the resulting laminagraphs would have been acceptable. It is interesting to note that if both the right and left condyles in this study were laminagraphed at the same machine angulation, 67.3 percent of the resulting radiographs would be of inferior quality if the criterion of ±3° is imposed.

The data indicated a significant difference in midline location when derived from machine and anatomical landmarks. The mean midline deviation of –.81 mm found earlier indicates the tendency for the headholder midsagittal plane to lie to the subject's left of the transporionic axis midline. This measurement is clinically insignificant from a machine tolerance viewpoint. However, it should be noted that the midline difference ranged from –5 mm to +4 mm and, at these extremes, failure to adjust for this difference would result in improper depth of cut values (Fig. 2).

As condylar angulation and the difference in depth of cut of the two techniques were related, a positive correlation exists for both the right and left sides (.37 for the right and .55 for the left). These correlations are both significant and show that, as the condylar angulation increases, the difference of the depth of cut increases. In other words, as the depth of cut measurement as determined in this study decreased, the related condylar angulation increased. This was due to the condyle moving closer to the midsagittal plane as the head was rotated a larger amount. As the condylar angulation increased, the need for consideration of head rotation and movement of the condyle to the midsagittal plane became increasingly

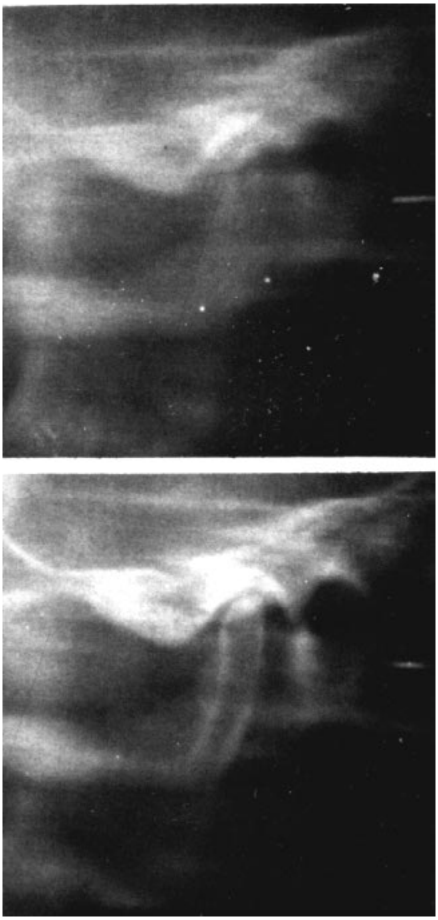

Fig. 2 The laminagraphs shown here are of the same temporomandibular joint. The depth of cut was determined using the method of Williamson and Wilson (above) and by the method described in this paper (below). Proper depth of cut setting has improved the clarity and diagnostic quality of the laminagraph.

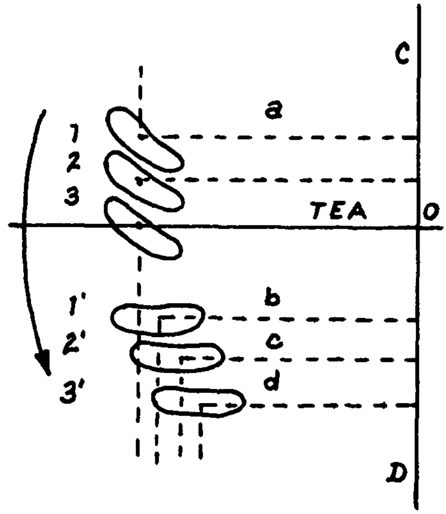

Fig. 3 Condyles (1,2,3) with the same angulation (40°) and equal distance to C-D (machine midline), but different distances to the transear rod axis. If depth of cuts were measured as suggested by Wilson,[9] laminagraphs of all three would be taken with the machine set at distance *a*. The subject's head, however, must be rotated in the headholder 40° to properly align the condyles with the X-ray beam. During head rotation the condyle follows an arc which causes it to change relative position. Note the relative positions to the headholder midsagittal plane of the same condyles (1', 2', 3') if the head were rotated 40°. Not only is the actual depth of cut measurement less than *a*, it also becomes increasingly less depending upon the condyle's original distance from the transear rod axis. Clinically, this can produce significant differences in laminagraph quality.

important. The significant positive correlation between condylar angulation and depth of cut ($P < .01$) indicates a tendency for this to be valid.

Using the different methods, it was discovered and statistically verified that two independent factors involve depth of cut determination. The combined effect of condylar angulation and position of the condyles relative to the ear rods may act to produce larger or smaller depth of cut values depending on their relation to each other (Fig. 3).

Negative condylar angulations, although they represent a small percentage of the population, are sometimes encountered. In such cases it must be kept in mind that in adjusting the machine, the head will be rotated in the opposite direction as in positive condylar angles. The condyle will be moving in the opposite direction relative to the *film* as it would in an individual with positively angulated condyles. This will not affect the direction the depth of cut indicator is moved in the lateral laminagraph, since lateral depth of cut is measured relative to the machine midsagittal plane (line C-D).

SUMMARY

The development of a practical laminagraph machine has done much to improve the quality of temporomandibular joint radiography. However, inaccurate machine setting for condylar angulation and depth of cut levels prevents operators from producing *consistently* clear laminagraphs of the joint.

The use of a preliminary basilar cephalogram analysis has been advocated for determining precise condylar angulations and depth of cut measurements on an individual basis. Although it represents a distinct improvement in laminagraphic technique, this analysis also has certain deficiencies.

The aim of this study was to evaluate the accuracy of the submentovertex analysis as described by Williamson and Wilson[8,9] by examining how the analysis satisfied the three criteria of: 1) correct magnification distortion adjustment, 2) proper midsagittal plane determination, and 3) accurate depth of cut determination.

An alternative method of preliminary analysis of basilar cephalograms was proposed and the two analyses compared on their conformance with the above criteria.

Significant statistical differences in the midsagittal plane measurements derived by the two methods were revealed. A considerable improvement in the quality of laminagraphs can now be obtained by utilizing the technique described in this paper. This will eliminate the need for the "shot gun" approach, thus reducing the radiation exposure to the patient.

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