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Distortion and Other Errors in Oblique Cephalometric Radiography

An evaluation of image distortion and serial variation in oblique cephalometric radiography. Reduction of inaccuracies from these sources is best achieved by aligning images of the inferior border of the mandible directly underlying the structures under study.

KEY WORDS: CEPHALOMETRICS, LATERAL JAW RADIOGRAPHY, RADIOGRAPHY, X-RAY

There are only sparse reports on oblique cephalometric techniques in the literature, but three studies have shown that considerable validity and accuracy are achievable (HATTON AND GRAINGER 1958, BARBER ET AL. 1960, BARBER ET AL. 1961). A previous five-year investigation by the Authors showed substantial correlations between oblique and lateral cephalometric radiographic findings (WINTER ET AL. 1974, WOELFEL AND WINTER 1975).

The purpose of this study is to identify errors in oblique cephalometric radiography that could affect the position of anatomical images on the radiograph. The major sources of such errors are:

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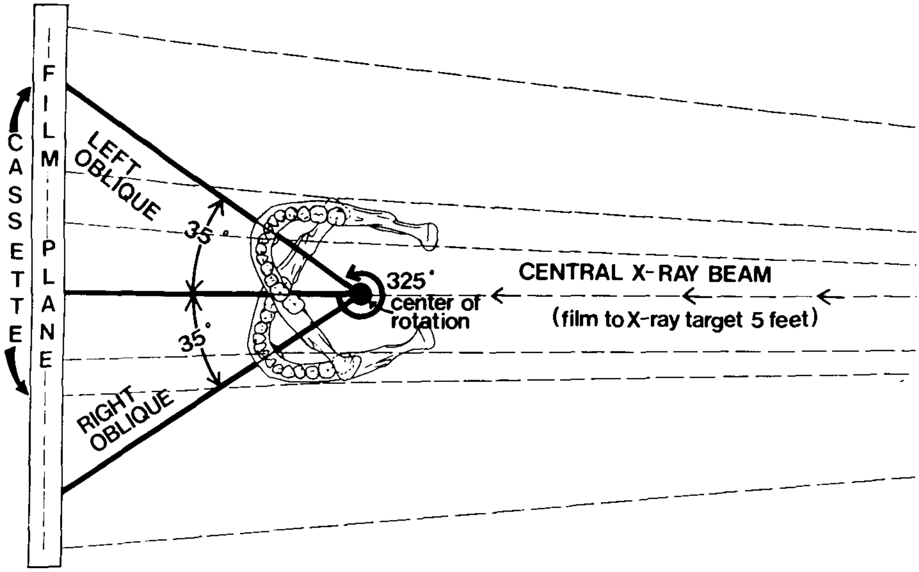

Fig. 1 Exact scale drawing (coronal view) of mandible in cephalostat for two comparable oblique radiographs. The solid circle is the center of cephalostat rotation. The x-ray beam originates 5ft (152.4mm) from the film. The right oblique and left oblique projections each use a 35° rotation away from the central x-ray beam.

Equipment

- Looseness of ear rods
- X-ray beam alignment with cephalostat

Patient positioning

- Tipping or rotation of the head
- Position of the mandible
- Position of dentures

Interpretation

- Alignment method used to orient images from different radiographs
- Bone recontouring between serial exposures
- Occlusal reconstruction or changed restorations
- Movement of dentures
- Attrition of teeth.
- Tooth movement - orthodontic, surgical, normal or abnormal migration

Equipment Alignment for Oblique Radiographic Projections

The x-ray source-to-film distance was fixed at 60 inches (152.4cm), and the distance from the rotational center of the cephalostat to the film was 7 inches (17.8cm) (Figs. 1 and 2).

Both 35° and 45° angulations were evaluated. The 35° cephalostat angulation shows more of the anterior portion of the mandible than the 45° angulation (Fig. 3). This requires a rotation of 55° in either direction from the 90° lateral cephalometric position. With the patient positioned in the cephalostat for a postero-anterior radiograph, directly facing the cassette with the x-ray beam entering through the back of the head (0° cephal-

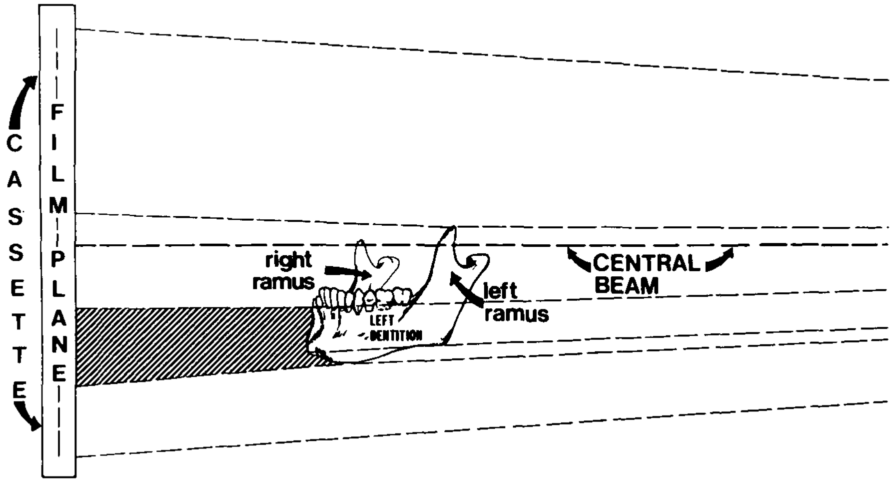

Fig. 2 Exact scale drawing (side view) of mandible in cephalostat for a right oblique radiograph. The shaded area indicates approximately how the x-ray beams diverge from the dental arch to the film, resulting in some elongation of the image of dental structures (see Table 2). The right side of the dentition and body of the mandible which will appear clearly on this right oblique radiograph are not seen on this illustration. The x-ray beams entering the distal of the left ramus pass forward in such a manner that all of the left-side structures are superimposed on a 35° right oblique radiograph.

ostat angulation), the head is rotated 35° to bring the side under study toward the film (Fig. 1). On cephalostats calibrated in a full 360° circle, this is usually at the 35° and 325° positions.

Subjects

Initial evaluations were done with a dry skull, with small steel balls demarcating selected regions.

Further evaluations were made on edentulous subjects with denture landmarks provided by the metal pins in porcelain anterior teeth and special amalgam fillings.

The alignment method for all tracings was that used in a previous investigation (Winter et al. 1974, Woelfel and Winter 1975). In this report, most orientations were on the lower border of the mandible directly below the ridge segment being analyzed, recognizing that Björk (1955) has shown with metal implants that both apposition and resorption of bone occur in some instances at the posterior inferior border of the mandible.

— Findings —

Change in Distance from the Skull Mandible to the Film With Cephalostat Rotations

Measurements were made from nine points on the right side of the dry skull mandible to the film for both 35° and 45° right oblique cephalostat angulations (Figs. 4 and 5). Eight of the nine selected points were farther from the film in the 45° position than in the 35° position

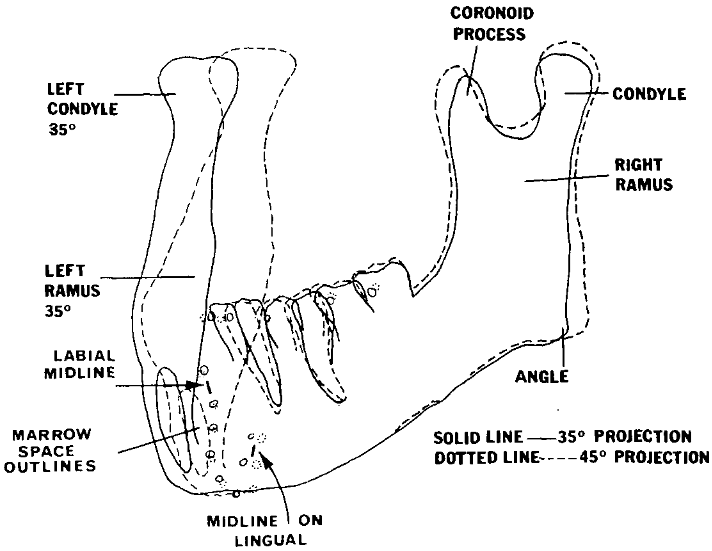

Fig. 3 A tracing made from a 35° right oblique radiograph (solid lines) was then aligned over the 45° oblique radiograph (dotted lines). The greatest difference in outlines with the 10° rotation of the cephalostat is in the width of the vertical portions of the opposite ramus, causing it to spread laterally and overlap the right alveolar ridge in the incisor and cuspid regions.

(Table 1). The one exception was the right mandibular angle, which moved 5mm closer to the film as the cephalostat was rotated from 35° to 45° (bottom of Table 1).

The position of the angle of the mandible relative to the cephalostat center caused the mandibular angle to move closer to the film with the 10° cephalostat rotation from 35° to 45°.

Comparable measurements for other points in the left oblique cephalostat angulation showed slightly different effects. The cuspid moved away from the film as on the right, but the four points in the left bicuspid and molar regions remained at almost the same distance from the film in either rotational position.

These differences were attributed to a difference in arch form on the two sides, a factor which can have equally potent effects in panoramic radiography (Fig. 5). The left molars were positioned more lingual, with the body of the mandible bowed out buccally in the second molar region. This curved left posterior dental arch rotated as part of a large circle centered near the center of rotation. The two midline balls on the mandible moved away from the film about 1cm with the 10° rotations on both right and left sides.

The greatest difference in outlines of the mandible resulting from the 10° rotation of the cephalostat between 35° to 45° was in the width of the vertical portion of the opposite ramus. This causes it to overlap the image of the anterior teeth, obstructing the view of three anterior teeth on the 45° projection (Fig. 6). The right ramus image is slightly wider anter-

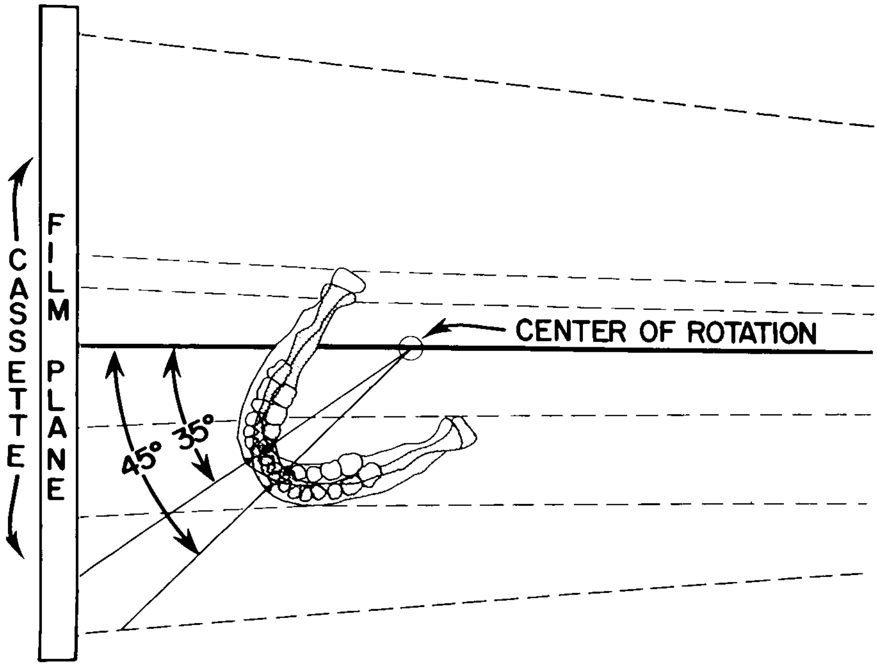

Fig. 4 Coronal view of mandible in cephalostat for two right oblique radiographs, one made at 35° and the other at 45° from the central x-ray beam (heavy solid line). The solid outline of the mandible and teeth show the 35° cephalostat angulation. The shaded outline represents the 45° angulation. Notice that the 10° increased angulation causes the teeth on the right side to move forward and slightly away from the film, whereas the right mandibular angle and condyle moves closer to the film. The teeth on the left side move primarily in a lateral direction, perpendicular to the x-ray beam and parallel to the film.

oposteriorly on the 45° projection because the 10° additional cephalostat rotation moves it more nearly parallel to the film, while the left-side ramus becomes less parallel to the central beam of the x-ray.

All of the teeth were elongated vertically and moved forward with the 45° cephalostat angulation (Fig. 6). This forward movement of the teeth, coupled with the wider image of the opposite ramus, influenced our decision to select the 35° angulation for our complete denture research program rather than the more commonly used 45° (Winter et al. 1974, Woelfel et al. 1976).

Vertical Distortions

Figs. 3 and 4 show what takes place when the rotational angle of the cephalostat is changed 10°, and how the changes affect the image. Steel balls glued onto the mandible at the midline and in eight more posterior positions showed elongation of all nine vertical dimensions on the radiographs (Fig. 6) (Table 2).

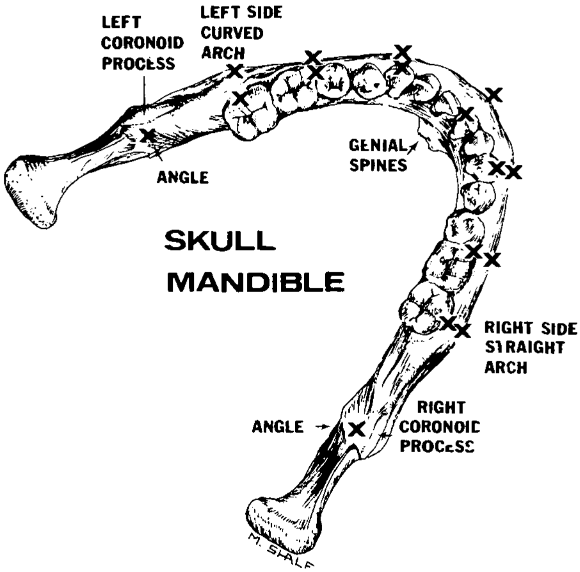

Fig. 5 Drawing of skull mandible and teeth, showing the curved left-side dental arch with the teeth in a lingual location. The right-side dental arch form is straight anteroposteriorly. Points selected for measuring purposes are indicated by an ×. The points measured on the left side of the dental arch closely followed the arc of rotation when the cephalostat was rotated 10° from 35° to 45°, as there was very little change in their distance to the film (Table 1).

This vertical enlargement of the image on the film was less on the 35° image in every instance (18 comparisons). Enlargement averaged 4% on the 35° images and 5% and 7% on left and right 45° images.

The smaller vertical distortion with 35° oblique projections is the result of the shorter distance from the area of interest to the film. The asymmetry of the skull, position of the ear holes, and variation in arch form described earlier all contribute to some of the percentage differences shown in Table 2.

Horizontal Distortions

Horizontal changes were evaluated in the same way, with reference points selected for broad coverage of the mandible (Fig. 7). Not all of the points used for vertical measurements were used for horizontal determinations because horizontal distances between some of them were too small for meaningful measurement.

Of particular interest in this study was the alveolar ridge crest region that was found to be important in the five-year study of mandibular resorption in forty-five edentulous patients (Winter et al. 1974).

All but one of the horizontal distances on the skeletal mandible (line G in Fig. 7) were foreshortened on the 35° oblique film, whereas vertical distances in the same region were elongated. As shown in Fig. 3, there was a discernible difference between bone and tooth outlines on films exposed at 35° and 45°.

On the 35° oblique radiographs, ten of

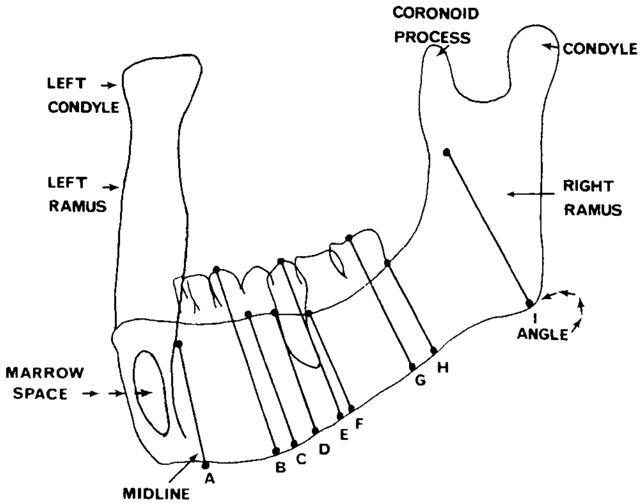

Fig. 6 Outline of the skull mandible and teeth, showing the nine regions (lines A through I) where vertical determinations were made on comparable oblique radiographs (Table 2).

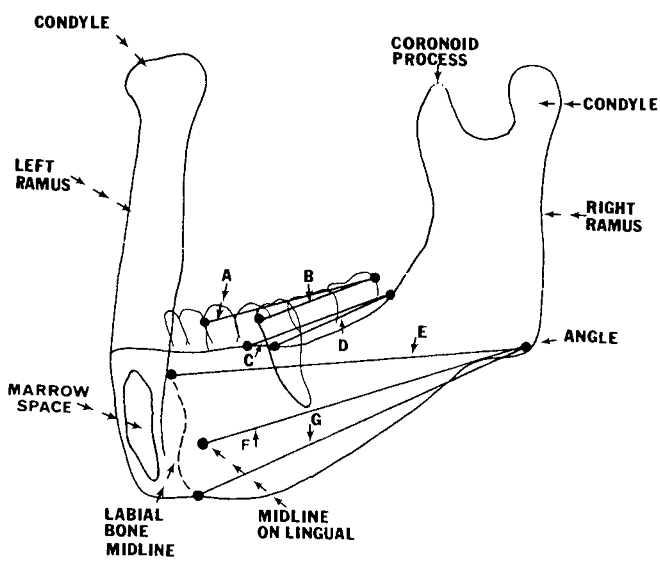

Fig. 7 Outline of the skull mandible and teeth showing the location of the seven regions (lines A through G) where horizontal determinations were made on comparable oblique radiographs (Table 3). In every instance the oblique films made at 45° cephalostat angulation showed elongation of the seven horizontal zones. However, on the 35° oblique radiographs, 10 of these 14 zones (7 per side) were foreshortened (Table 3).

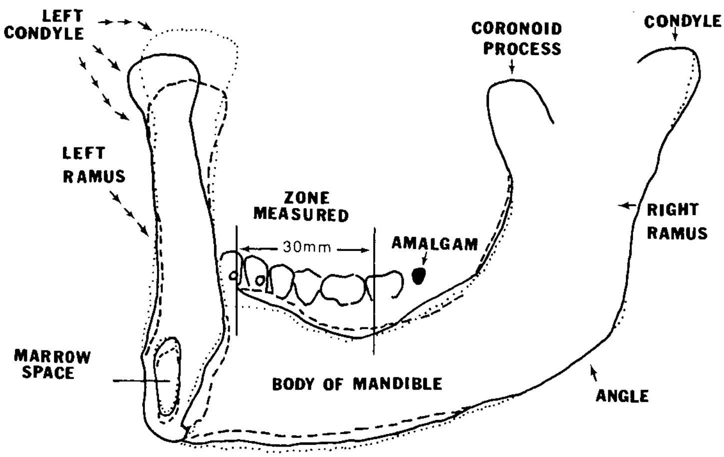

Fig. 8 Composite right-side 35° oblique tracing showing the effect of three different vertical positions of the mandible — rest position, wide open, and maximal closure with dentures removed. The alignment of images was mainly on the lower border of the mandible and the outlines of the anterior and posterior borders of the ramus. The solid lines show rest position, the dotted lines are the image of the jaw wide open, and the interrupted lines indicate the image of maximum closed position of the jaw. A single solid line means that the three images coincided.

the fourteen measurements were shortened. On the left-side projection, all horizontal lines except G (angle to midline) were shortened an average 3.0%. On the right side, the four horizontal distances in the region of the crowns of the teeth and ridge crest were shortened, while the three measurements from the angle of the mandible to the midline were elongated slightly.

However, the oblique films made at 45° showed 1.4% to 8% elongation of the fourteen horizontal dimensions, with overall averages 3% on the left and 5% on the right side (Table 3).

The differences between right and left side distortion are attributable to the same anatomical asymmetries mentioned earlier.

Correlation of Skeleton Findings With Commonly Encountered Uncontrollable Factors

Subject Variation

Having found the nature of both horizontal and vertical radiographic distortions of a dentulous skull, diagnostic radiographs of two edentulous patients wearing dentures were exposed to enable comparison of their horizontal distortions to those found with the skull (Table 4). Dimensional changes are shown rather than percentages.

The distance from midline to first molar ridge crest was enlarged about 1mm on both sides of the skull mandible, but on the patients this distance was shortened about 3mm.

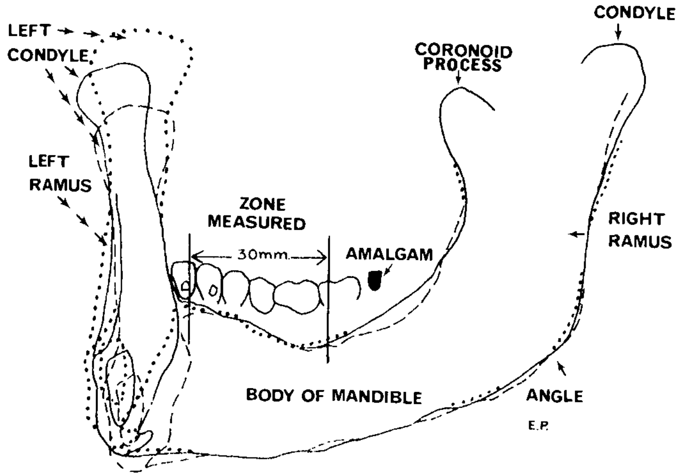

Fig. 9 Composite right-side 35° oblique tracing showing the effect of rotating the head vertically in the cephalostat — solid lines show correct positioning in relation to infraorbital pointer, dotted image shows head tipped downward 5mm, and interrupted lines head rotated upward 10mm above normal. The primary guide in aligning the images from the three oblique x-rays was the inferior border of the mandible underlying the teeth. A single solid line means that the three images coincided.

On the right and left oblique projections of the skull, the horizontal distances from cuspid to second molar were shortened on the 35° films and elongated on the 45° films. On two patients, the cuspid-to-second molar distances were shortened on both the 35° and 45° projections, with the exception of one 45° projection on the left side, where that dimension was enlarged.

For the midline to distal of second molar, the skull images were considerably elongated for all exposures, but the reverse was again true for the two patients, with 0.1mm to 5.4mm shortening (Table 4).

These dissimilarities between radiographic projections on comparable oblique angulations of several mandibles are due to asymmetry and the form of the dental arch, and their effects on the relationship of the mandible to the film.

Such anatomic variables can undoubtedly vary beyond the ranges found in these samples, but they will nevertheless be consistent for the individual patient.

Variation in Rest Position on Nervous Patients

When several radiographs must be made with the mandible in physiologic rest position, there is no reliable method for assuring that all will be exposed with the jaw in exactly the same position. When the interval between films is several years, the variation may be even greater.

There is seldom a problem with lateral cephalometric films because well- established anatomic landmarks make it possi-

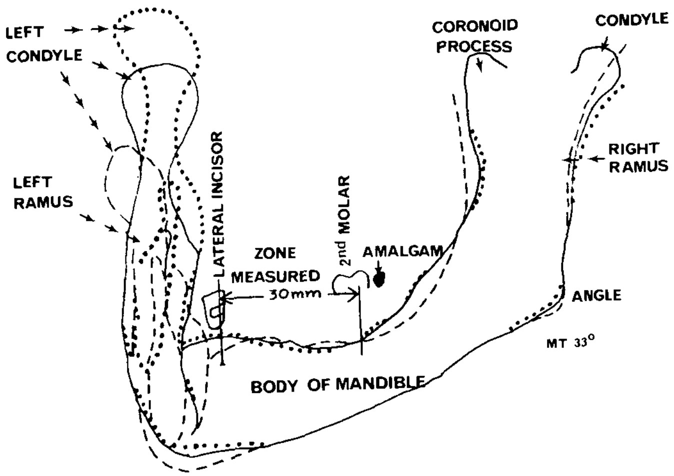

Fig. 10 Composite right-side 35° oblique tracing of same three radiographs shown in Fig. 9 (head rotated vertically in cephalostat), demonstrating some of the pronounced effects of incorrect alignment of images. The main guide for the alignment of the three images shown here was the lower border of the mandible posterior and anterior to the teeth (single solid line). Notice the wide separation of the three coded lines at both the ridge crest and the inferior border of the mandible, which could lead to erroneous interpretation.

ble to determine the actual position of the mandible from the relationships of menton, pogonion, the angle and other mandibular landmarks to cranial landmarks.

Those landmarks are not available on oblique radiographs, so some other method for identifying variations in the resting position of the mandible is needed. Centric occlusion can provide such an index when enough teeth are present, but occlusal levels may also change with attrition.

In the edentulous patient, denture settling can have an even greater effect on mandibular position, even in centric occlusion.

Patient anxiety can also seriously degrade accurate reproducibility.

The purpose of this study on nine patients was to find out from actual measurements how much vertical error was introduced into alveolar ridge height from the mandibular border by alteration of physiologic rest position. Nine patients judged to be unstable in rest position were selected from a group of forty-five (Winter et al. 1974, Woelfel and Winter 1975).

To determine how much variation in the mandibular rest position occurred among these nine patients, the vertical dimension of rest position was assessed by comparison with a master acetate guide with the locations of clearly distinguishable landmarks on the cranium and mandible punched. Identical landmarks were identified, punched and measured at denture insertion and on either the fifth, eighth or ninth year oblique radiographs.

The data in Table 5 shows the dimensional variation in rest position for these nine nervous patients over intervals of five to nine years. The largest change was

Table I

Movement of several Points on Images of Right* and Left** sides of Skull Mandible when Cephalostat was Rotated between 35° to 45° Oblique Projections

Point on side of Mandible	Skull-to-Film Distance: Right Side Oblique 35°	45°	Change	Left Side Oblique 35°	45°	Change
Ball #9 at midline near incisor	120.0	129.0	+9.0	118.5	129.0	+10.5
Ball #5 at midline near border	122.2	131.0	+8.8	121.5	134.0	+12.5
Cuspid Tip	115.0	121.0	+6.0	105.5	109.0	+3.5
Lower Border below Cuspid	120.0	126.0	+6.0	122.0	125.0	+3.0
Ridge crest between 2nd Bic and 1st Molar	118.2	122.0	+3.8	114.5	114.0	−0.5
Lower border between 2nd Bic and 1st Molar	125.6	130.0	+4.4	126.0	127.0	+1.0
Center of 2nd Molar Cusp tip	125.3	128.5	+3.2	124.0	124.0	0.0
Lower border below 2nd Molar	129.8	132.5	+2.7	130.0	130.0	0.0
Angle of Mandible	149.0	144.0	−5.0	143.0	138.0	−5.0

* The arch form on the right side is almost a straight line from cuspid to 2nd molar, so these distances all changed during the rotation from 35° to 45°.

** The arch form on the left side is bowed out from cuspid to 2nd molar, so these points on the mandible more nearly follow the arc of rotation from 35° to 45°, as indicated by small changes in the bicuspid and molar distances.

*** Measurements for right oblique views are from right side of the mandible to film, and for left views are from left side of mandible to film.

a decrease of 5.2mm in a male, the smallest a 2.0mm decrease found in two females. Four of the nine showed mandibular closure ranging from 3.1mm to 4.0mm. A 3.1mm opening was found in one female and 3.2mm in a man.

While the −5.2mm maximum change in rest position may seem large, it is only ⅛ of the 40mm distance represented by the extreme range of the mandible from wide open to a maximum closed position (Fig. 8). Considering the relatively small range of variability of mandibular posture found in this group of nervous patients, the overall effect on oblique radiographic measurements can be considered to be very small.

This information supports the validity of cross-sectional area measurements of five-year bone loss on forty-five patients previously reported (Winter et al. 1974).

Good correlation was also established between standard lateral 90° cephalometric radiographs and 35° oblique radiographs in five-year comparisons of vertical dimension changes and mandi-

Table 2

Differences (%) between Vertical Distances measured on the Skull and Corresponding Dimensions on the Oblique Radiograph

Vertical Distance shown in Figure 3	Left oblique		Right Oblique	
	35°	45°	35°	45°
A	+4.5%	+5.7%	+5.3%	+7.2%
B	+1.4%	+2.6%	+3.8%	+4.3%
C	+4.8%	+5.8%	+6.3%	+10.8%
D	+4.7%	+5.3%	+2.7%	+4.7%
E	+3.2%	+5.0%	+3.5%	+6.0%
F	+4.0%	+4.7%	+2.7%	+4.3%
G	+5.2%	+7.0%	+5.9%	+7.8%
H	+3.8%	+5.4%	+2.2%	+5.8%
I	+4.6%	+5.1%	+4.1%	+12.0%
Average Enlargement	+4.02%	+5.18%	+4.1%	+7.0%

Table 3

Differences (%) between Horizontal Distances Measured on the Skull and Corresponding Dimensions on the Oblique Radiograph

Horizontal Distance as shown in Figure 4	Left Oblique		Right Oblique	
	35°	45°	35°	45°
A	−4.2%	+3.7%	−2.5%	+3.7%
B	−5.4%	+1.9%	−0.4%	+2.9%
C	−4.1%	+3.5%	−1.5%	+2.0%
D	−7.9%	+1.4%	−1.5%	+4.4%
E	−0.7%	+3.0%	+1.9%	+8.0%
F	−0.1%	+2.9%	+2.1%	+6.9%
G	+1.6%	+3.6%	+3.3%	+7.4%
Average	−2.97%	+2.86%	+0.2%	+5.04%

Table 4

Changes in Horizontal Image Size (mm) between Two Different Oblique Projections Using a Dry Skull and Two Patients

Region Measured	Subject	LEFT Actual Distance	Distance on Film 35°	45°	RIGHT Actual Distance	Distance on Film 35°	45°
Cuspid Center to Distal of 2nd Molar	Skull	38.0	36.4	39.8	37.5	36.8	38.7
	M.T. 33°	33.9	31.9	34.9	34.3	31.5	33.8
	R.G. 0°	32.1	30.5	32.6	34.2	28.8	32.5
Mesial 1st Bic to Distal of 2nd Molar	Skull	34.0	32.7	35.3	34.3	33.5	35.1
	M.T. 33°	31.5	28.8	32.0	31.9	28.4	30.7
	R.G. 0°	29.2	26.4	29.0	31.0	25.0	28.9
Midline to Ridge Crest at Mesial of 1st Molar	Skull	29.1	31.2	31.3	29.0	30.3	30.3
	M.T. 33°	26.5	22.6	23.0	26.8	23.5	23.9
	R.G. 0°	26.2	23.5	23.6	27.4	24.2	24.8
Midline to Distal of 2nd Molar	Skull	47.2	50.5	52.1	46.8	50.5	51.3
	M.T. 33°	44.0	40.4	43.3	44.0	40.2	42.2
	R.G. 0°	43.6	41.6	43.5	45.2	39.8	43.3

Table 5

Variation in Rest Position on Nervous-Type Denture Patients over an Eight-year Period (Right side, 35° Oblique View)

Recorded as the distance (mm) on a 35° right obligue radiograph between estimated menton and the upper rim of the left orbit near the zygomatic process of the frontal bone

Patient and Occlusal Group		Insertion	5th year	8th or 9th year	Greatest Variation
M.T.(F)	33°	130.0	130.0	128.0	−2.0
E.S.(M)	33°	139.2	138.1	134.0	−5.2
D.B.(M)	33°	134.5	133.0	130.5	−4.0
A.N.(F)	20°	120.1	118.2	117.0	−3.1
W.L.(M)	20°	137.5	133.9	137.5	−3.6
A.H.(F)	20°	124.0	119.5	122.0	−2.0
R.R.(M)	0°	136.2	135.5	133.0	−3.2
D.F.(F)	0°	119.0	120.0	122.1	+ 3.1
H.S.(M)	0°	147.0	150.2	149.8	+ 3.2

bular resorption evaluated in centric occlusion (WINTER ET AL. 1974, WOELFEL ET AL. 1975).

Further investigation of the vertical position of the mandible and how a change of this position would effect oblique radiographic images is explained in the next section of this report.

Variation From Opening and Closing the Mandible

To determine what types of oblique image distortion can occur with specific changes in the vertical position of the mandible, three right oblique cephalometric radiographs (35°) were made at one sitting on the same patient — one with the mandible at rest position, one with maximal opening of the jaw, and a third with maximal closure of the mandible with the dentures removed. We minimized any effect due to head rotation in the cephalostat (see next section) between the three radiographs by aligning the infraorbital pointer with an indelible mark on the patient's skin.

A master acetate tracing was made of the radiograph of the mandible in rest position with the dentures in place (solid line in Fig. 8). This tracing was then carefully aligned on the radiograph made with the mouth opened as wide as possible (dotted outlines), and then over the radiograph made with the mouth closed as far as possible with the dentures removed (interrupted outlines).

The best superimposition of the master mandibular tracing over each radiograph was achieved, mainly by the alignment of the lower border of the mandible underlying the 30mm measuring zone, and by the most reasonable positioning of the anterior and posterior outlines of the ramus and angle of the mandible.

Where only a solid outline is seen in Fig. 8, all three radiographic images coincided using the method of alignment just described.

With the mandible wide open, there was a slight foreshortening of the distance from the inferior border of the mandible (solid line) to the image of the ridge crest (dotted lines), in relation to the solid rest position outlinexof the ridge crest (Fig. 8).

On the film of the mandible maximally closed, there was a slight vertical elongation of the distance from the inferior border of the mandible (solid line) to the image of the ridge crest (interrupted lines).

The greatest distance (most relative distortion) was 3mm seen anteriorly between the solid ridge crest line (rest position) and the interrupted line representing maximum closure. On the other hand, the dotted outline of the ridge crest (mandible wide open in Fig. 8) almost superimposed with the solid line showing rest position.

The small separation between the three ridge crest lines in the 30mm measured zone is insignificant. Except for the image of the opposite side of the mandible, the dotted outline (jaw wide open) follows the solid line (rest position) very closely in Fig. 8.

There was a little more separation between the maximum closure image (interrupted lines) and rest position image (solid lines), indicating slightly more distortion between these two jaw positions. As expected, the greatest overall discrepancy on the ipsilateral side was found between the images of the mandible maximally opened and maximally closed.

The radiographic image of the opposite side of the mandible was considerably elongated on the wide open film (note dotted outline in Fig. 8 from top of condyle to the region near menton). This same area was considerably foreshortened on the maximum closure film (interrupted line), because the jaw orientation is more horizontal in that position.

A direct effect of this type of distortion is reflected by the larger separation of the bony ridge crest outlines at the extreme anterior segment of the 30mm measuring zone (Fig. 8). Considering the wide range of mandibular position (wide open to maximum closed), the difference found between the three oblique images depicted by the coded lines was relatively small, particularly in the ipsilateral ridge crest region.

As explained in the following section, entirely different interpretations and possibly erroneous results are obtained when oblique radiographs are not aligned by landmarks directly underlying the region under scrutiny.

Variation from Rotation of Head in Cephalostat

To determine the distortion in oblique radiographs caused by rotation of a patient's head around the ear rods in the cephalostat, right- side 35° oblique radiographs were made with the teeth held firmly in centric occlusion — one with the head rotated so the infraorbital pointer was at the infraorbital notch (Frankfort plane horizontal), one with the head intentionally tilted downward 5mm, and one with the head tipped upward 10mm above the horizontal position. This enabled direct evaluation of the effect of head rotation on distortions of the mandibular image on oblique radiographs.

The composite illustration (Fig. 9) was made by first tracing the oblique radiograph made with the head oriented horizontally (solid lines), then aligning this tracing on the film made with the patient's head tipped downward 5mm (dotted lines), and finally aligning it to the film made with the head tipped upward 10mm (interrupted line).

The specific anatomic structures used for aligning the tracing over the three films were the lower border of the mandible (cuspid to molar region) and the anterior and posterior borders of the ipsilateral ramus. The interrupted and dotted lines show where the distortion between the radiographs occurred when the head was tipped upward or downward.

Observe the close proximity of the dotted, interrupted and solid outlines of the bony ridge crest within the 30mm measuring zone, indicating that there was minimal vertical distortion in this region when the tracing was aligned with the lower border of the mandible lying directly below.

The maximum distortion (horizontal and vertical) occurred on the opposite image of the ramus and body of the mandible. With the head tipped downward 5mm from normal (dotted line), the vertical height of the contralateral mandibular image was elongated 7mm more than the comparable image made with the head oriented to the Frankfort horizontal plane (solid line).

By tipping the head upward 10mm beyond normal orientation, the vertical dimension of the image of the contralateral side of the mandible (interrupted line in Fig. 9) was 5mm less, yet the condyle image was 2mm wider than on the radiograph made with the head correctly positioned.

The oblique radiograph with the least overall distortions was the one with the head oriented to the Frankfort horizontal plane (solid line in Fig. 9).

Less error was produced on the side of the jaw under scrutiny by rotating the head downward 5mm than when it was rotated upward 10mm (interrupted lines). The importance of aligning serial tracings of radiographs by anatomic landmarks directly inferior to the region under scrutiny cannot be overstressed. The profound effect of using different structures is shown below.

Variation Caused by Incorrect Alignment of Tracings

To demonstrate the effect of improper alignment of tracings made from oblique radiographs, a second tracing was made from the centric occlusion radiograph with the head correctly positioned in the cephalostat. This tracing was then aligned over the other two oblique films (head tipped downward and upward), using principally the anterior lower border and angle of the mandible (Fig. 10), rather than the inferior border underlying the posterior teeth as previously described and recommended (Fig. 9).

The inappropriate method of aligning the tracings seen in Fig. 10 produced an entirely different result — neither the ridge crest outlines nor the outlines of the inferior border of the mandible below the 30mm zone on any pair of the three films was superimposed. In fact, the ridge crest outlines were separated by 1.5 to 3mm, indicating how grossly incorrect interpretations might be made from oblique projections improperly aligned.

The recommended method of alignment, using the inferior border of the mandible directly below the region under scrutiny as shown in Figs. 1, 8 and 9, minimized the effects of distortions, especially in the region of the bony ridge crest, whereas the alignment shown in Fig. 10 magnified them.

— Discussion —

With the knowledge gained by studying the effect of errors in oblique radiography caused by variations in subjects, position, head rotation in the cephalostat, and alignment of tracings, we have determined that some of these factors may be minimized (Figs. 1, 8 and 9) or magnified (Fig. 10) by choice of alignment method.

The governing factors are distance from the film, which controls magnification, and angulation to the film, which controls foreshortening.

Any conclusions made from serial oblique radiographs without first testing the effect of known variables on the method employed to align serial tracings could be erroneous. An accurate analysis from cephalometric radiographs involves exact identification of anatomic structures seen on radiographs as well as a knowledge of their spatial relationships and constancy with time (Moore 1971, Winter et al. 1974).

— Conclusions —

Some of the major errors in oblique cephalometric radiography can be eliminated or reduced by paying attention to small detail, by testing the validity of the alignment method against known variables, and by continuous observation of the patient's position in the cephalostat and jaw position prior to and during each exposure.

Changing the rotational angle of the cephalostat 10°, as between 35° and 45°, can have a considerable effect on foreshortening or elongation of the mandibular image, depending on the cephalostat angulation and the portion of the dental arch structures being studied.

Vertical enlargement of the bony image of the mandible and teeth on the oblique radiographs was less with the 35° cephalostat angulation than with the more common 45° angle, yet at 35° the horizontal dimensions of the same images were foreshortened 0.4% to 7.9%. Generally, the entire half of the mandibular dental arch was visible on the 35° radiographs, but the incisor region was not clearly discernible on the 45° films because of overlapping of the contralateral image.

We have demonstrated that error due to the expected variability in mandibular physiological rest position on nine nervous patients over a nine year period was negligible compared to several other factors.

The error produced in oblique radiographs by purposely having a patient's jaw opened the maximum amount on one film and then closed the maximum amount on another film, or by tilting the head downward 5mm or upward 10mm for two additional oblique radiographs, was negligible or could be minimized by careful alignment of the tracings.

Reduction of error in oblique radiography from all of these sources depends largely on a reliable tested method of alignment of the tracings. Very careful selection and identification of the anatomic landmarks on each film to be used cannot be overstressed. Alignment of serial oblique radiographs on the lower border of the mandible directly below the region being analyzed has proven to provide a reliable basis for serial comparison.

References

Barber, T.K.; Pruzansky, S.; and Kindelsperger, R. 1961. An evaluation of the oblique cephalometric film. *J. Dent. Children* 28:94-105.

Barber, T.K.; Pruzansky, S.; and Lauterstein, A. 1960. Application of Roentgenographic Cephalometry to Periodontic Research. *J. Dent. Children* 27:97-106.

Björk, A. 1955 Facial growth in man, studied with the aid of metallic implants. *Acta. Odont. Scand.* 13:9.

Hatton, M.E., and Grainger, R.M. 1958. Reliability of measurements from cephalomgrams at the Burlington Orthodontic Research Centre. *J. Dent. Res.* 37:853-9.

Moore, A. W. 1971. Cephalometrics as a diagnostic tool. *J. Am. Dent. Assoc.* 82:775-81.

Winter, C.M.; Woelfel, J.B.; and Igarashi, T. 1974. Five year changes in the edentulous mandible as determined on oblique cephalometric radiographs. *J. Dent. Res.* 53:1455-67.

Woelfel, J.B., Winter, C.M.; and Igarashi, T. 1976. Five year cephalometric study of mandibular ridge resorption with different posterior occlusal forms. *J. Prosth. Dent.* 36:602-23.