Is Orthopantomography Reliable for TMJ Diagnosis? An Experimental Study on a Dry Skull

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The accuracy of orthopantomography in reproducing the temporomandibular joint area was analyzed on a dry skull. The results based on this study of a single skull revealed that the radiographic image of the temporomandibular joint did not correspond to the anatomic condylar and fossa components or to their actual relationships. To a large extent, changes in skull position affected the radiographic temporomandibular joint image, simulating anterior condylar flattening, osteophytes, narrowing of joint space, and left/right condylar asymmetry. Orthopantomography may have questionable reliability for temporomandibular joint diagnostic purposes.

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Although the use of orthopantomography (OPG) for temporomandibular joint (TMJ) imaging is controversial,[1–4] the American Academy of Pediatric Dentistry[5] and the American Academy of Orofacial Pain[6] have recommended panoramic radiography as an initial imaging technique for TMJ screening when the clinical examination suggests some form of joint pathology. In recent years, the image distortion of the TMJ in OPG has been discussed in several studies.[2,7] However, the results of these studies cannot be transferred easily to the clinical situation. Therefore, the aim of this investigation was to *(1)* analyze the TMJ orthopantomographically with respect to which anatomic structures of the joint area correspond to the contours displayed on the OPG and to *(2)* evaluate the effect of changes in skull position on the radiographic TMJ image.

Materials and Methods

A dry skull with a complete maxillary and mandibular dentition and a normal appearance of the mandibular condyles and the glenoid fossa was selected. The OPGs were taken with an Orthopantomograph 5 (Siemens, Bensheim, Germany). Exposure data were 65 kV, 15 mA, and 15 seconds. Kodak T-MAT G 100 film was used for all radiographs.

All OPGs were taken with the skull in maximum intercuspal position and both condyles centered in the fossae, simulating the spatial anatomy of the joint area in clinical subjects. The maximum intercuspation was assured with a silicone interocclusal record. A piece of foam rubber interpositioned between the condyle and the glenoid fossa took the place of the disc. The mandible was secured to the skull by steel wires.

To achieve a true image of the temporal component of the TMJ, brass wire markers were positioned in the lateral, central, and medial third of the glenoid fossa, covering its whole anteroposterior extension. Furthermore, three parts of the condylar head were marked with different markers:

1. A piece of straight brass wire for the lateral pole
2. A looped brass wire for the medial pole
3. A round low profile orthodontic button for the posterior pole

A supporting device constructed for the skull enabled positioning of the skull in the orthopantomograph. The device allowed free rotation of the skull around the horizontal, sagittal, and transverse axes. The rotational changes could be read with an accuracy of 1 degree. A rotation of 1 degree corresponded to a 0.28-cm change in skull position.

Fossa Analysis

First, the skull was radiographed in an "ideal" position (ie, according to the manufacturer's instructions) without the opaque fossa markers (native image). Next, the skull was radiographed with all three wire markers placed in the glenoid fossa. Thereafter, the wire markers were eliminated successively. The OPGs taken of each change were superimposed over the initial one to assess which parts of the temporal fossa made up the native fossa image.

Condyle Analysis

To analyze the influence of changes in skull position on the radiographic image of the condyle, the OPGs were taken in the following skull positions:

1. Ideal position
2. Inclined posteriorly (retroclination)
3. Inclined anteriorly (anteclination)
4. Tilted laterally to the left
5. Rotated horizontally to the left
6. Simultaneous position changes in two different dimensions (a combination of positions 2 to 5)
7. Simultaneous position changes in three different dimensions (a combination of positions 2 to 5)

All position changes were performed in 1-degree steps to a maximum of 4 degrees when evaluating changes in one dimension, and to 2 degrees when evaluating simultaneous changes in two or three dimensions.

The condylar images were evaluated for changes in the following:

1. Form and position of the condyle in the glenoid fossa
2. Condylar marker projection
3. Condylar height

The changes in form and relative position of the condyle in the glenoid fossa were assessed according to the method used by Wood.[8] The following distances were measured (Fig 1):

- a = Distance from the squamotympanic fissure to the midpoint of the condyle (S'-M).
- b = Distance from the midpoint of the condyle to the articular eminence (M-E').
- c = Distance from the midpoint of the condyle to the reference line (R1). Projections of M below R1 were assigned positive values, and projections of M above R1 were assigned negative values.
- d = Distance from the anterior condylar border to the posterior condylar border (Ca-Cp). This distance was considered to be the condylar width.

The changes in the projections of the condylar markers at the posterior, medial, and lateral poles were evaluated using the following distances (Fig 2):

- x = Distance between the anterior and posterior borders of the orthodontic button marker at the posterior pole (Pa-Pp).
- y = Distance between the posterior border of the looped brass wire marker at the medial pole and the anterior border of the orthodontic button marker at the posterior pole (M-Pa).
- z = Distance between the anterior border of the marker at the lateral pole and the posterior border of the orthodontic button marker at the medial pole (L-M).

The changes in condylar height were evaluated according to the method used by Kjellberg et al.[9] The condylar height (co'-inc'), the total ramus and condylar height (co'-go'), and the ramus height (inc'-go') were measured, and the following ratios were calculated (Fig 3):

1. co'-inc':co'-go'
2. co'-inc':inc'-go'

All the measurements from the OPGs were made to the nearest 0.5 mm. The registrations were performed twice, and the mean value was used for the evaluation.

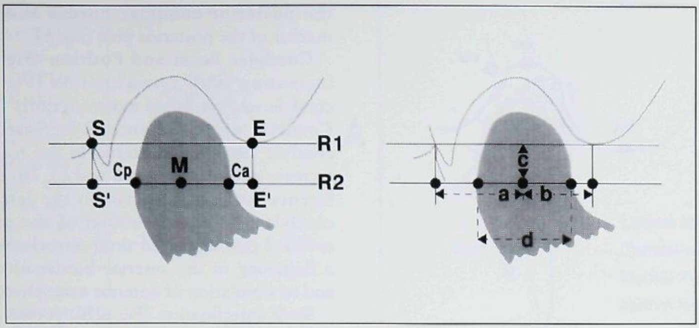

Fig 1 Evaluation of condylar form and position.[8] The interconnecting line (R1) between the squamotympanic fissure and the articular eminence and a line (R2) parallel to R1 through the midpoint of the condyle serve as reference lines. The following reference points are used: the squamotympanic fissure (S); the midpoint of the condyle (M); the articular eminence (E); the point of intersection between R2 and the anterior condylar border (Ca); and the point of intersection between R2 and the posterior condylar border (Cp). The points S and E are perpendicularly transferred to the R2 line and assigned as S' and E', respectively. Distances a (S'-M), b (M-E'), c (M-R1), and d (Cp-Ca) are measured.

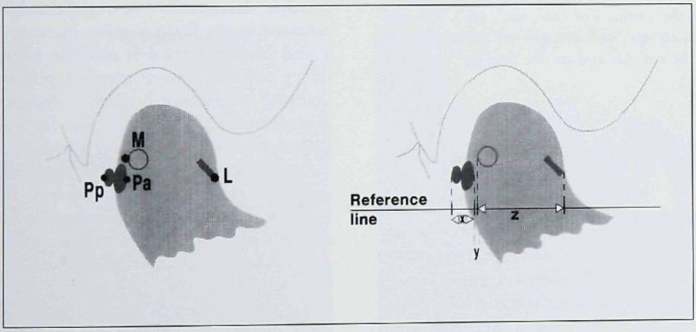

Fig 2 Analysis of condylar marker position. The following reference points are assessed: anterior border of the marker of the lateral condylar pole (L), posterior border of the marker of the medial condylar pole (M), anterior border of the marker of the posterior condylar pole (Pa), and posterior border of the marker of the posterior condylar pole (Pp). These points are perpendicularly transferred to a line parallel to the upper border of the OPG (reference line). Distances x (Pp-Pa), y (Pa-M), and z (M-L) are measured.

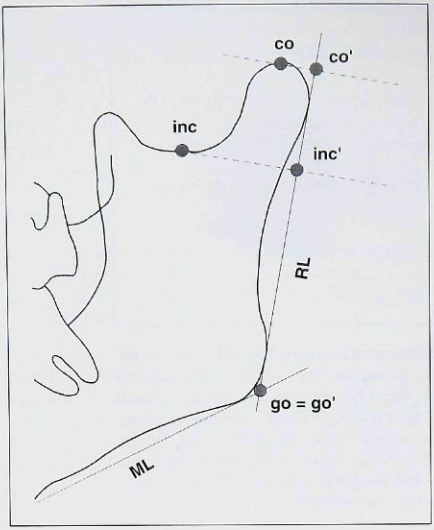

Fig 3 Assessment of condylar height.[9] Reference points co (condylion = most superior point of the condylar head), inc (incisura mandibulae = the deepest point between processus coronoideus and condylion) and go (gonion = the intersection between ramus line [RL] and mandibular line [ML]) are assessed and perpendicularly transferred to the ramus line (co', inc', go'). The distances co'-inc', co'-go', and inc'-go' are measured, and the ratios co'-inc':co'-go' and co'-inc':inc'-go' are calculated.

Results

Fossa Analysis

The glenoid fossa as projected by the standard OPG was a superimposition of different components of the anatomic fossa. In this particular skull, the left fossa image resulted mainly from a superimposition of the medial and lateral fossa markers. The right fossa image resulted mainly from a superimposition of the lateral and central fossa markers (Fig 4).

Condyle Analysis

In the ideal skull position, the lateral condylar pole was visualized on the OPG as the anterior border of the condyle. The posterior pole was visualized correctly as the posterior border of the condylar image. The medial pole, on the other hand, was superimposed over the center of the condyle near the posterior condylar border and above the marker of the posterior pole (Fig 5).

Condylar Form and Position (Fig 6). With increasing skull retroclination (Fig 6[A]), the condyle was projected more inferiorly (distance c). Condylar width (distance d) increased while the condyle remained centered in the fossa (similar increase of the distances a and b). No marked difference was found between the left and right condyles. Visual inspection of the radiographs revealed that increased skull retroclination lead to a flattening of the anterior border of the condyle and to simulation of anterior osteophytes (Fig 7).

Skull anteclination (Fig 6[B]) projected the condyle more superiorly (distance c). Condylar width decreased (distance d). The condyle remained centered in the fossa (similar change of the distances a and b). No marked difference was found between the left and right condyles. Visual inspection of the radiographs revealed that an increased skull anteclination lead to a continuous decrease of the joint space with an almost complete closure (Fig 7).

A lateral tilt of the skull to the left side had opposite effects on the right and left condylar images (Fig 6[C]): the right condyle was projected superiorly; and the left condyle was projected inferiorly (distance c). The width of the right condyle (distance d) increased, but the width of the left condyle decreased. The right condyle remained centered in the fossa (similar increase of distances a and b), while the left condyle exhibited a tendency toward a more anterior projection (larger decrease of distance b than of distance a). Visual inspection of the radiographs did not show any irregularities of the condylar image.

During left rotation of the skull, no clear tendency in the change of the condylar form was detectable (Fig 6[D]). This was true for both the right and left condyles. Visual inspection of the radiographs did not show any irregularities of the condylar image.

Combined changes of skull position in two and three dimensions affected the condylar image, but no clear tendency in the changes was detectable.

Marker Position. No change in skull position had an effect on the radiographic image (distance x unchanged) of the posterior pole of the left and right condyle (Fig 8).

Anteclination of the skull projected the medial pole of the left and right condyle more posteriorly (decrease in distance y). Retroclination projected the medial pole more to the center of the condyle (increase in distance y). Left rotation and left tilt of the skull did not change the marker projection significantly (distance y unchanged).

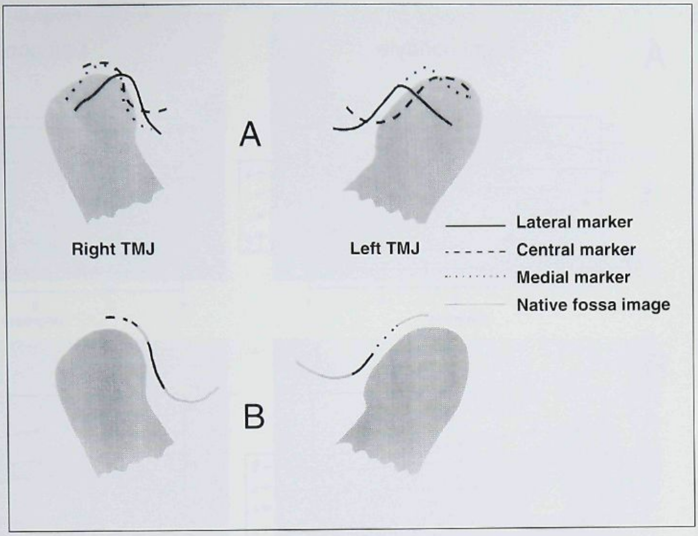

Fig 4 Tracings of the left and right TMJ radiographic image as displayed on OPGs taken in ideal skull position. A = radiographic images of the opaque markers at the lateral, central, and medial third of the glenoid fossa with respect to the condylar image. B = radiographic images of the glenoid fossa markers, which match the contour of the native fossa image on an OPG taken without opaque markers.

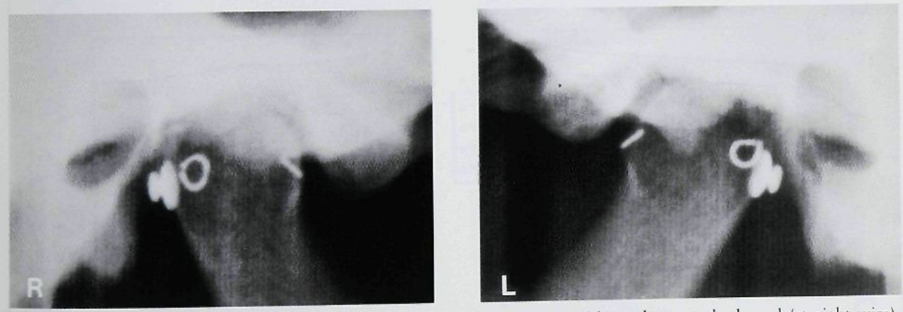

Fig 5 Orthopantomogram of the right (R) and left (L) condylar regions with markers on the lateral (straight wire), medial (looped wire), and posterior pole (orthodontic button) of the condylar head.

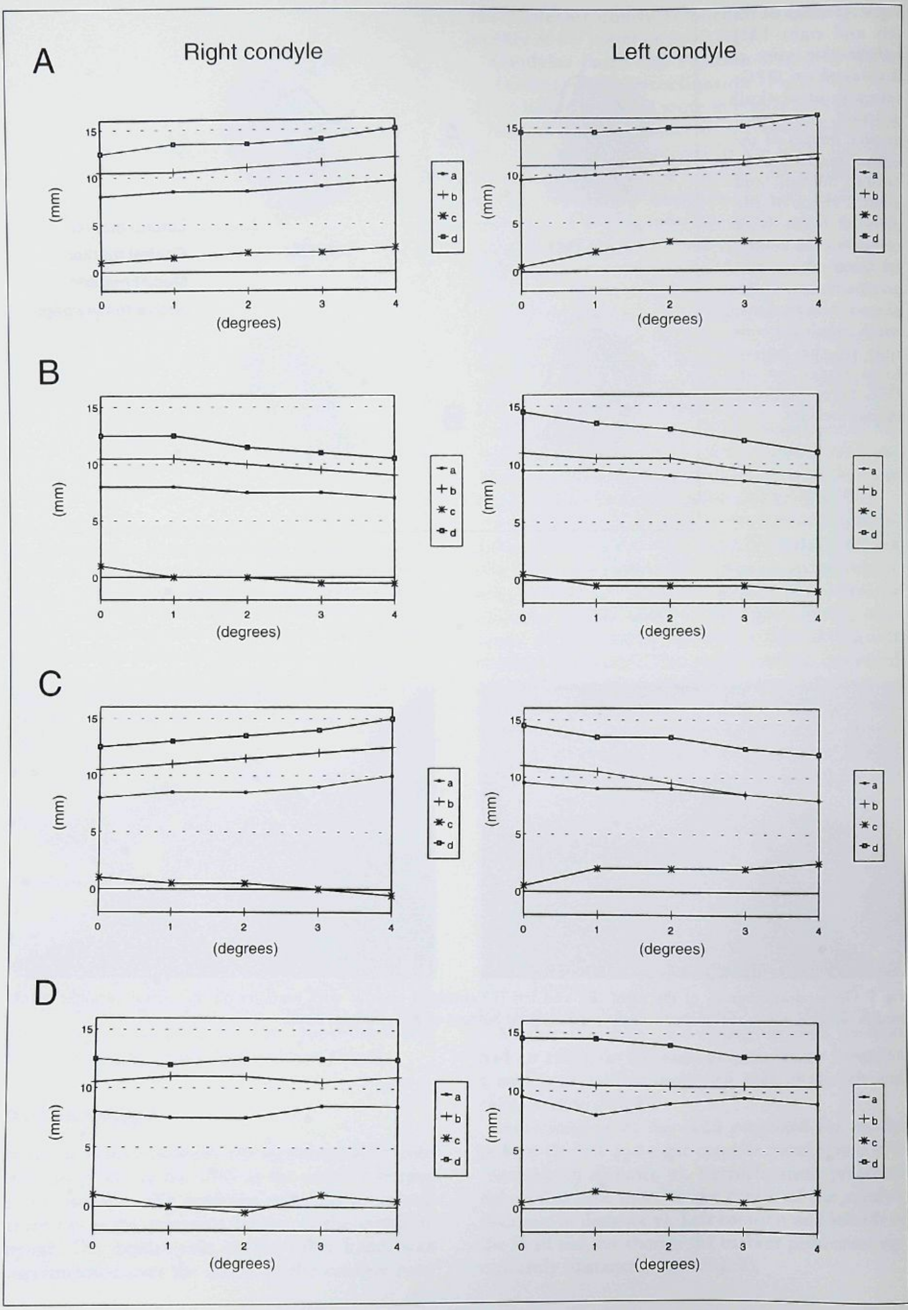

Fig 6 Changes in condylar form and position (mm) as a result of skull position changes (degrees). A = retroclination; B = anteclination; C = left tilt; D= left rotation. Distances: a (S'-M), b (M-E'), c (M-R1), and d (Cp-Ca).

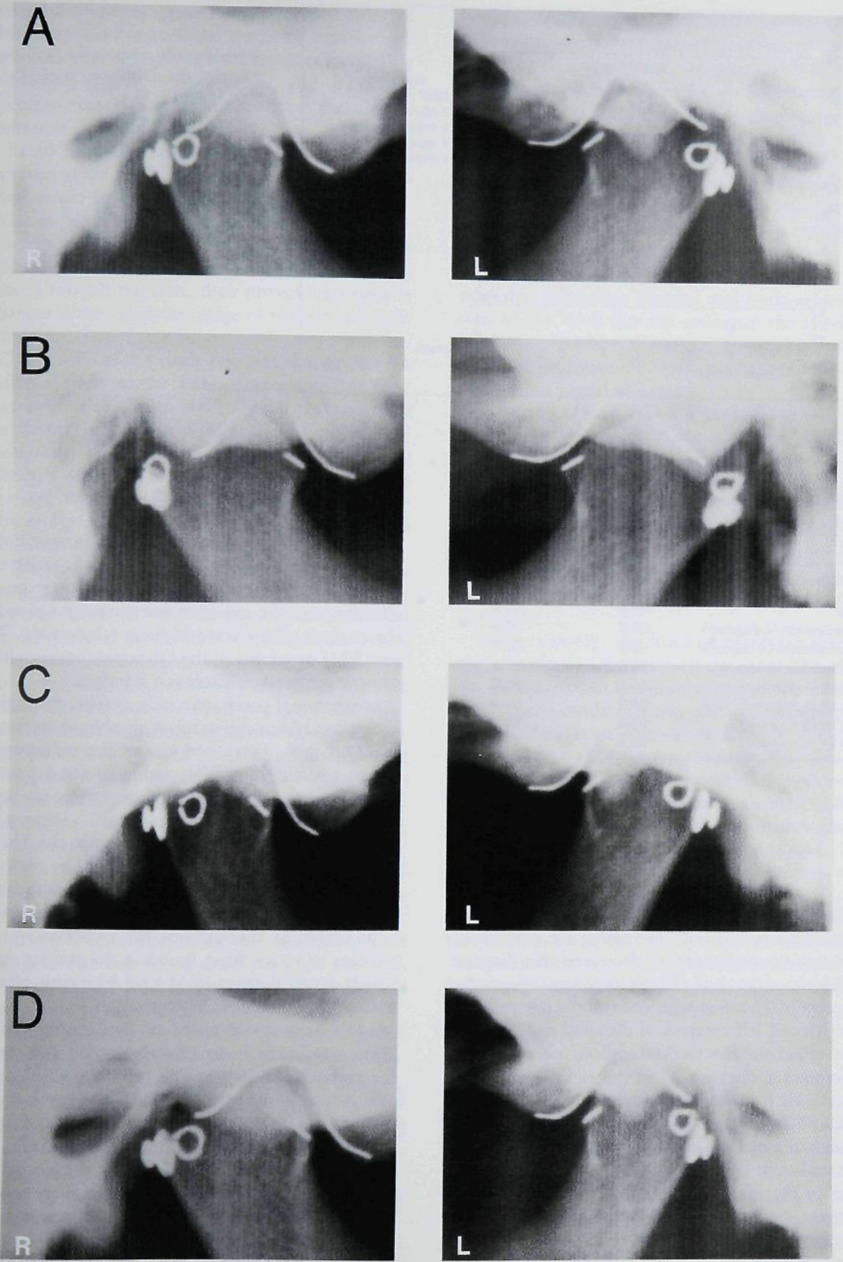

Fig 7 The right (R) and left (L) condyles as visualized on OPGs taken in different skull positions. For better identification of the glenoid fossa, the fossa marker in the lateral third is in place. A = ideal position; B = retroclined position (flattening of the anterior border and the anterior limbing); C = anteclined position (narrowing of the joint space); D = lateral tilt (difference between the left and right condylar sizes).

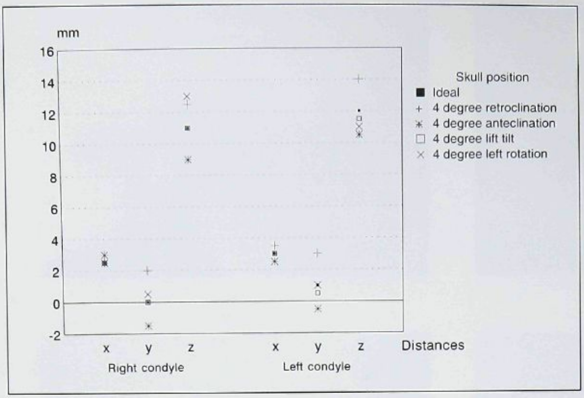

Fig 8 Changes in the marker projection (mm) of the right and left-condyles with respect to skull position changes. Distances: x (Pp-Pa), y (Pa-M), and z (M-L).

Table 1 Changes in the Relative Height (%) of the Right and Left Condyles With Respect to Skull Position Changes

Skull position	co'-inc':co'-go'	co'-inc':inc'-go'
Ideal	98.0	96.8
Anteclination (4 degrees)	98.5	97.6
Retroclination (4 degrees)	98.5	97.7
Left rotation (4 degrees)	98.5	97.6
Left tilt (1 degrees)	96.1	93.3
Left tilt (2 degrees)	96.7	94.8
Left tilt (3 degrees)	90.4	84.9
Left tilt (4 degrees)	85.9	78.3

Retroclination of the skull affected the projection of the lateral pole, increasing the intermarker distance (z); anteclination decreased this distance. A left tilt of the skull did not have any influence on distance z. This was true for both the left and right condyles. A left rotation of the skull had an opposite effect on the two condyles, increasing the intermarker distance (z) in the right condyle and decreasing it in the left condyle.

Condylar Height. Only a lateral tilt of the skull had a marked effect on the relative size of the left and right condyles (Table 1 and Fig 7). In relation to the ideal skull position, a lateral tilt of 4 degrees resulted in a condylar height difference (asymmetry) of a maximum of 18.5% between the two condyles.

Discussion

According to the manufacturer's instructions, orthopantomographs should be taken with the mandible in a protruded position. However, many clinicians use the maximal intercuspal position for the analysis of the condyle-fossa relationship. The new TMJ programs of the Orthopantomograph 10 use this centered position as a standard.

In rotational panoramic radiography, the outline of the condyle in the image is an oblique section of the TMJ area. Form and size of the radiographic image and the interrelationship of the anatomic structures vary with the direction of the x-ray beam and are basically a result of projection geometry.

The x-ray beam direction relative to the TMJ is affected by head position changes and by condylar form as well as by the size of the mandible. Because condylar form and mandibular size were kept constant throughout the experiment, the changes in image form found in the present study result from distortional and blurring effects induced by changes in head position.

The image is composed of two central projections, one in the horizontal dimension and one in the vertical dimension. The beam's vertical direction is fixed upward to the TMJ; as a result of this inclination, structures closer to the source of radiation are projected farther above the structure. The horizontal beam direction affects the horizontal image. Structures outside the zone of sharpness are distorted and blurred because their movement is greater or less than film speed. Therefore, structures displaced toward the film are projected on less film distance and, thus, decrease in size; objects inclined toward the center of rotation are projected over a larger film distance, consequently increasing in size. Both blurring and distortion effects increase with the distance from the zone of sharpness.

Retroclination causes the condylar area to be intersected more obliquely by the x-ray beam in comparison to the standard position, while anteclination leads to a straighter intersection. During a lateral tilt, one condyle is inclined toward the center of rotation, and the other condyle is displaced toward the film, thus provoking opposite changes in the condylar image of the left and right condyles.

The results of this study revealed that neither the different parts of the TMJ components nor their anatomic relationship were reproduced correctly on the OPGs taken in maximum intercuspal position. This is in agreement with the study by Uotila,[10] who demonstrated that the glenoid fossa is poorly imaged in an OPG. Therefore, an evaluation of the condyle-to-fossa relationship by means of orthopantomography does not seem suitable.

The effects of changes in skull position on the condylar marker images corresponded to the distortional effects on condylar form. As a result of an altered direction of the central radiographic beam, progressive retroclination, anteclination, and lateral tilt of the skull resulted in a continuous increase and/or decrease of the four measured distances used for describing condylar form and position (see Fig 6[A to C]). On the other hand, progressive lateral rotation of the skull led to discontinuous changes in the measured distances (see Fig 6[D]). This might be the result of a combination of various distortional and blurring effects.

The various changes in condylar form induced by combined skull position changes in two or three dimensions were the result of an additive and/or subtractive interaction of the one-dimension changes. The combined skull position changes, however, did not lead to any additional findings in comparison to the one-dimension changes.

Visual inspection of the OPGs revealed that retroclination of the skull resulted in anterior flattening of the condyle and osteophytic formations. Because condylar flattening and the presence of osteophytes are among the classic radiographic signs of degenerative TMJ changes,[11,12] the described distortional effects might be misinterpreted as signs of temporomandibular disorders (TMD).

A narrowing of joint space is reported to be concomitant with some kinds of TMD.[13] However, because an increase in skull anteclination resulted in a continuous decrease of anterior, posterior, and upper-joint space, an assessment of the condyle position on the OPG by measuring joint space seems contraindicated for diagnostic purposes.[6] Furthermore, anteclination of the skull caused the medial condylar pole to be projected more distally, partially overlapping the marker of the posterior pole. This may lead to a denser image of the posterior condylar area, simulating a sclerosis.

In agreement with Kjellberg et al,[9] anterior and posterior inclination changes and horizontal rotation of the skull did not influence the left-right condylar symmetry. However, a lateral tilt of the skull did influence the symmetry between the two condyles to a marked extent.

It can be argued that the analysis of only one skull, and thus of only one anatomic condylar form and mandibular size, will not be representative for condylar imaging by orthopantomography. No doubt, the metrical changes found in the present study are specific for this particular skull, but the principles of distortion and blurring in rotational panoramic radiography obviously apply for other condylar forms and mandibular sizes in the same way.

Unfortunately, the kind of condylar form is always unknown in a clinical situation. Therefore, we cannot predict the distortional effects induced by different condylar forms and variances in position resulting from different mandibular sizes.[14–16] As demonstrated in the present study, the high sensitivity of the orthopantomographic projection of the TMJ area, even to very small changes in head position, should cause the validity of orthopantomographic TMJ imaging to be questioned. This technical conclusion is compatible with the results of a clinical TMJ study by Bush et al[17] that demonstrated that no association exists between the findings on panoramic radiographs and clinical TMJ signs and symptoms, possibly as a result of a misinterpretation of distortion effects as signs of temporomandibular disorders.

Conclusion

The image of the TMJ area as seen on OPG films does not necessarily correspond to the anatomic condyle and fossa components, nor does it accurately depict their relationship. Changes in head position during orthopantomography can affect the condyle and fossa images to a marked extent, leading to anterior condylar flattening, simulation of osteophytes, joint-space narrowing, and left/right condylar asymmetry. Thus, orthopantomography has potential limitations from a TMJ diagnostic standpoint.

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Resumen

Es la ortopantomografía confiable en la diagnosis de la articulación temporomandibular? Una investigación experimental en un cráneo seco

La precisión de la ortopantomografía en reproducir la región de la articulación temporomandibular fue analizada en un cráneo seco. Los resultados revelaron que la imagen radiografica de la articulación temporomandibular no corresponde ni a las partes anatómicas del cóndilo y la fosa ni a su relativa posición. Cambios de posición del craneo afectaron la imágen radiográfica en gran parte simulando un aplanamiento del margen anterior del cóndilo, la presencia de osteofitos, una reduccion del espacio articular e una asimetría condilar entre el lado derecho e izquierdo. En conclusión la ortopantomografía no es confiable para propósitos diagnósticos de la articulación temporomandibular.

Zusammenfassung

Ist das Orthopantomogramm für die Kiefergelenksdiagnostik geeignet? Eine experimentelle Untersuchung an einem mazerierten Schaedel

Die Genauigkeit der Orthopantomographie hinsichtlich der Darstellung der Kiefergelenksregion wurde anhand eines mazerierten Schädels überprüft. Die Ergebnisse zeigten, daß das radiologische Bild der Kiefergelenke weder in der Lage war die anatomischen Komponenten des Condylus und der Fossa korrekt wiederzugeben noch deren aktuelle Lagebeziehung darzustellen. Veränderungen der Schädelposition im Orthopantomographen beeinflußten das radiologische Bild des Kiefergelenkes beträchtlich. Sie führten zu einer Abflachung und Randzackenbildung am vorderen Kondylusrand, einer Abnahme der Gelenkspaltbreite und zu einer Rechts-Links-Asymmetrie der Kondylen. Folglich ist die Nutzbarkeit des Orthopantomogramms für die Kiefergelenksdiagnostik fragwurdig.