Condylar height on panoramic radiographs

A methodologic study with a clinical application

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The aim of this study was to develop and apply a reliable method of measuring the effects of condylar lesions quantitatively on panoramic radiographs. Three different types of machines were tested. Two dry skulls were exposed in six positions in each machine, and the relative size of the condyle in relation to ramus height was calculated. The results showed good validity for the reference points used. The head position did not contribute to the variation in the measurements, but the type of panoramic machine had some influence. It was concluded that the method may be applied when calculating condylar ratios, provided that the same panoramic machine is used. The relative height of the condyle in relation to ramus height was measured bilaterally in three groups of children, with either normal of postnormal occlusion or with juvenile chronic arthritis (JCA), to detect possible asymmetries and define differences in the relative condylar height. The JCA group had a significantly shorter relative condylar height, and asymmetries were commoner than in the other two groups. □ *Angle class II; juvenile rheumatoid arthritis; mandibular condyle; morphometry; orthopantomography*

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Rotational panoramic radiography is widely used in clinical dentistry because it is simple and the radiation dosage is low. The measurements in panoramic radiographs, however, include considerable methodologic errors. In the sharply depicted plane the image is free of distortion, which means that the magnification factor is the same in both the vertical and the horizontal plane. Objects outside this layer, however, will appear distorted in the image owing to the difference between the velocity of the film and the velocity of the projection of the object on the film. The panoramic image is therefore affected by both magnification errors and displacement (1, 2). The horizontal distances are particularly unreliable as a result of the non-linear variation in the magnification at different object depths, whereas vertical distances are relatively reliable (1, 3–7). For this reason Ramstad et al. (8) suggest that quantitative measurements on panoramic radiographs should be abandoned. However, other authors (1, 6, 7) find that the reproducibility of vertical and angular measurements is acceptable provided that the patient's head is correctly postitioned in the equipment.

It is also essential to use the same type of panoramic machine in longitudinal studies, since different panoramic machines have different projection geometries, which are all attempts to approximate an average jaw. This will result in differences in magnification and in the amount of distortion and displacement of structures (2, 5, 9).

Even though the use of panoramic radiographs is connected with large methodologic pitfalls, some quantitative methods have been used for linear measurements, such as tooth length (6), edentulous ridge height (8), and mandibular dimensions (7, 10, 11).

In diseases involving the temporomandibular joint (TMJ), such as arthritis, several studies have used panoramic radiography for the diagnosis of deviation from normal

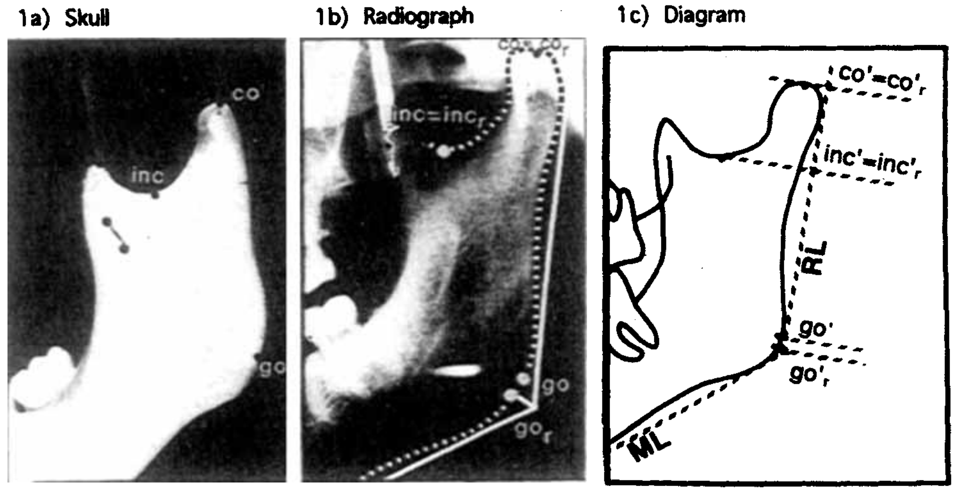

Fig. 1a. Metal markers on the dry mandible corresponding to the anatomic points co, inc, and go. 1b. A panoramic radiograph with the metal markers indicating co, inc, and go and the anatomic points drawn from the panoramic radiograph co_r, inc_r, and go_r. In the present radiograph co = co_r and inc = inc_r. 1c. The reference points were transferred to the ramus line (RL): co′, co'_r, inc′, inc'_r, go′, and go'_r. In the present radiograph co′ = co′, and inc′ = inc'_r. The validity of the reference points was calculated from the differences co'_r–co′, inc'_r–inc′ and go'_r–go′. The condylar height (co'_r–inc'_r), total height of ramus and condyle (co'_r–go'_r), and ramus height (inc'_r–go'_r) were measured to estimate the condylar ratios co'_r–inc'_r/co'_r–go'_r% and co'_r–inc'_r/inc'_r–go'_r%. For definition of the points, see text.

condylar joint morphology (12–17). To our knowledge, only a few studies (11, 18) have dealt with measurements of condylar and ramus height to define asymmetries between the left and right side. Quantitative evaluation of the effects of condylar lesion has not been attempted yet but could be a useful and perhaps more objective supplement to qualitative observations.

The aim of this study was thus to develop a method, independent of the magnification factor, to determine the condylar height on the panoramic radiograph and, furthermore, to apply this method in children with and without condylar lesions.

Methodologic study

Craniometric assessments

On two dry skulls, one of a 7-year-old child and one of an adult, metal markers (1.0 × 0.5 mm) were inserted on the mandible on both sides, as seen in Fig. 1a. The markers correspond to the anatomic points co, inc, and go, defined as follows: co = condylion (the most superior point on the condylar head); inc = incisura mandibulae (the deepest point between processus coronoideus and processus condylaris); and go = the gonion point, the intersection between the ramus line (RL) and the mandibular line (ML) on the mandibular border.

Good agreement between the authors in identifying the points and good accuracy in marking the anatomic points were found.

The linear distance co-go (Fig. 1a) was measured twice with a caliper, directly on the skull, with an interval of 1 week between the measurements. The mean value of the two measurements was considered 'the true anatomic distance'.

Radiographic assessments

Three different panoramic machines at the Department of Oral Diagnostic Radiology, University of Göteborg, were tested: Cranex

(Soredex, Orion Corporation Ltd, Helsinki, Finland), OP 10 (Instrumentarium Imaging, Helsinki, Finland), and PM 2002 C (Planmeca Oy, Helsinki, Finland). The mean magnification described by the manufacturer was 1.23 for the OP 10, 1.2 for the PM 2002C, and 1.3 for the Cranex.

The skulls were exposed in the following six positions in each of the panoramic machines: a) an optimum position according to operating instructions; b) positioned 10 mm anteriorly (towards the film); c) 10 mm posteriorly (towards the rotation center); d) rotated horizontally 15° to the right side; e) tilted backwards 10°; and f) tilted forwards 10°.

The exposures were repeated for each head position on the adult skull in one of the panoramic machines (PM 2002C).

The anatomic points co, inc, and go are represented on the radiograph by the metal markers (Fig. 1b). Furthermore, the corresponding radiographic points are indicated and called co_r, inc_r, and go_r (since the points with metal markers did not always correspond to the ones showed radiographically). Finally, all these points were transferred to the ramus line (RL), to calculate measurements in the vertical dimension. The corresponding points on the ramus line were given a prime sign ('), co'_r, inc'_r, go'_r, co', inc', and go' (Fig. 1c). All measurements were made to the nearest 0.1 mm.

The magnification of co-go in the panoramic radiograph was calculated from the ratio $\text{co-go}_{radiograph}/\text{co-go}_{skull}$. This was performed in each panoramic machine for each head position.

To test the validity of the reference points, the differences $co'_r - co'$, $inc'_r - inc'$, and $go'_r - go'$ were calculated.

To calculate the relative condylar height, two condylar ratios ($co'_r\text{–}inc'_r/co'_r\text{–}go'_r$ and $co'_r\text{–}inc'_r/inc'_r\text{–}go'_r$) were used. The reason for using a ratio instead of linear measurements was that differences in magnification did not need to be considered.

Statistical methods

The means and standard deviations of the magnification of co-go were calculated for the different machines and head positions.

The validity of the reference points is presented as the mean of the differences co–co_r, and so forth, and by 95% confidence intervals.

Analysis of variance was used to evaluate the effect of changing the head position and of using different panoramic machines on the ratios $co'_r\text{–}inc'_r/co'_r\text{–}go'_r$ and $co'_r\text{–}inc'_r/inc'_r\text{–}go'_r$.

All measurements in both the methodologic and clinical parts were performed by one of the authors (H. Kjellberg).

Table 1. The mean magnifications and standard deviations of co-go in the different head positions are calculated from the ratio $\text{co-go}_{radiograph}/\text{co-go}_{skull}$ ($n = 4$ (two skulls, left and right condyle)). The mean magnifications for the different machines described by the manufacturer are listed in parentheses

	Machine (magnitude)					
	PM (1.20)		OP10 (1.23)		Cranex (1.30)	
Head position	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Standard pos.	1.19	0.02	1.17	0.02	1.20	0.02
Pos. 10 mm ant.	1.19	0.02	1.16	0.02	1.20	0.02
Pos. 10 mm post.	1.20	0.02	1.17	0.02	1.21	0.02
Rot. 15° to the right	1.19	0.04	1.17	0.03	1.20	0.04
Tilt. vert. 10° ant.	1.20	0.02	1.16	0.02	1.19	0.03
Tilt. vert. 10° post.	1.18	0.02	1.17	0.01	1.21	0.02

Table 2. Analysis of variance. Dependent variables (Y): co'_r–inc'_r/co'_r–go'_r and co'_r–inc'_r/inc'_r–go'_r. Independent variables (x): x_1 = head position ($n = 6$), x_2 = panoramic machine ($n = 3$), x_3 = skull ($n = 2$), and x_4 = left or right condyle ($n = 2$)

Dependent variable Y	SD^2 (x_1)	SD^2 (x_2)	SD^2 (x_3)	SD^2 (x_4)	R^2
co'_r–inc'_r/co'_r–go'_r,%	0.00	1.32	3.28	0.33	0.71***
co'_r–inc'_r/inc'_r–go'_r,%	0.00	5.36	13.86	1.58	0.71***

Results and conclusion

The mean magnification of the distance co-go, based on measurements from the right and left sides of both skulls, varied from 1.16 to 1.21 mm, with a larger variation between the machines than between the different head positions tested. Disparity was also found between the mean magnification factor given by the manufacturer and the calculated ones. The highest agreement between the present measurements and those given by the manufacturer was for the PM 2002C (Table 1).

Measuring the validity of the reference points showed total concordance between inc'_r and inc' ($\bar{x}_{diff.inc'} = 0.00 \pm 0.00$ mm), but a small systematic error was found for co' and go' ($\bar{x}_{diff.co'} = -0.14 \pm 0.05$ mm and $\bar{x}_{diff.go'} = 0.52 \pm 0.12$ mm), caused by difficulty in determining the anatomic point in a projection using an oblique beam direction. Co' was positioned slightly inferior to co'_r, specially on the right side of the child's skull, and go' was positioned slightly superior to go'_r, mainly on the left side of the adult skull.

The influence of head position and different panoramic machines on the condylar ratios (co'_r–inc'_r/co'_r–go'_r and co'_r–inc'_r/inc'_r–go'_r) was tested using analysis of variance (Table 2). The head positions (x_1) did not contribute to the variation of the ratios measured ($SD^2x_1 = 0.00$), which was also confirmed by duplicate exposures of each head position on the adult skull in the PM 2002C machine ($SD^2x_1 = 0.00$). This may be compared with results from previous studies (1, 4, 19) in which different head positions influenced the image, although only to a minor extent in the posterior region.

The type of panoramic machine (x_2) used had a greater impact ($SD^2x_2 = 1.32$ and 5.36). This is in agreement with the results of Lund & Manson-Hing (5), although they studied linear measurements instead of a ratio.

The observed variation in the measured ratios between the skulls (x_3) was naturally high ($SD^2x_3 = 3.28$ and 13.86), reflecting differences both in size and age, whereas the variation between the left and right side of the skulls was low ($SD^2x_4 = 0.33$ and 1.58).

In conclusion, the calculated magnification in the specific region measured does not always correspond to the mean magnification given by the manufacturer; the validity of the constructed points (co'_r, inc'_r, and go'_r) is good; and the head position does not contribute to the variation of the measurements, as they are expressed in a ratio, whereas the type of panoramic machine has some influence. The present method may be applied when calculating the condylar ratio on panoramic radiographs, provided that the same panoramic machine is used.

Clinical application

The method was then applied in three groups of children to evaluate asymmetries and condylar height.

Subjects. a) The 'normal group' (Angle class I) consisted of 40 children, 15 boys and 25 girls (mean age, 10.0 years; range, 7–16 years), without any history of diseases or any signs or symptoms of craniomandibular disorders, with neutral sagittal occlusion and neutral basal relationships as defined by lateral cephalometry. All the children were selected from among children registered for orthodontic treatment at the Department of orthodontics, University of Göteborg, and referred to the Department of Oral Diagnostic Radiology during the period 1982–91. The reasons for referral were minor orthodontic problems such as slight crowding, rotated teeth, aplasia of single teeth, or other minor dental discrepancies.

b) The 'postnormal group' (Angle class II) consisted of 62 healthy children, 30 boys and 32 girls (mean age, 9.4 years; range, 7–12 years), with postnormal malocclusion. They were selected from among children registered for orthodontic treatment at the Department of Orthodontics, University of Göteborg, during 1986–90. The following criteria were used: bilateral distal molar relationship of at least one cusp width, an overjet of ≥7 mm and no transversal discrepancies.

c) The 'JCA group' consisted of 35 children with juvenile chronic arthritis (JCA), 12 boys and 23 girls (mean age, 11.2 years; range, 7–16 years), who were referred for odontologic examination from the Department of Paediatrics, East Hospital, University of Göteborg, because of symptoms from the stomatognathic system (TMJ or muscular pain, reduced mouth opening capacity, and/or mandibular underdevelopment) (for details, see Kjellberg et al. (20)).

In the present study most of the children (100% of the children with normal occlusion, 92% with postnormal occlusion, and 91% of the children with JCA) were examined with the OP5 or OP10 panoramic machine. According to the manufacturer, these panoramic machines have the same projection geometry, resulting in the same amount of magnification, distortion, and displacement of structures.

Method. Linear measurements were performed on the panoramic radiographs to the nearest 0.1 mm, using the reference points co, inc, and go, which correspond to the points co_r, inc_r, and go_r described in the methodologic part of the study (Fig. 1b). The condylar ratios (co'–inc'/co'–go' and co'–inc'/inc'–go') were calculated (Fig. 1c).

Asymmetries between the left and right condyle were calculated as the ratio of the highest to the lowest relative condylar height.

Statistical methods. The mean ($\bar{x}$), the standard deviation (SD), the standard error (SE), and the range were calculated for each group for both the left and right condyle.

Table 3. Descriptive statistics for the condylar ratios (co'–inc'/co'–go' and co'–inc'/inc'–go') from the right (r) and left (l) sides and for age, based on the measurements of the three patient groups (normal, postnormal, and juvenile chronic arthritis (JCA) group) studied in the clinical part

Variable	$\bar{x}$	SD	SE	Range
Normal group (N)				
age	10.0	1.9	0.3	7.8–16.1
co'–inc'/co'–go' (r)	34.8	4.8	0.8	23.7–45.4
co'–inc'/co'–go' (l)	34.4	4.9	0.8	22.3–48.5
co'–inc'/inc'–go' (r)	54.1	11.7	1.8	31.0–83.1
co'–inc'/inc'–go' (l)	53.3	12.1	1.9	28.7–94.2
Postnormal group (PN)				
age	9.4	1.1	0.1	7.4–12.4
co'–inc'/co'–go' (r)	32.4	4.3	0.5	25.4–41.7
co'–inc'/co'–go' (l)	32.7	3.6	0.5	25.4–42.3
co'–inc'/inc'–go'	48.6	9.5	1.2	34.1 71.6
co'–inc'/inc'–go' (l)	49.0	8.2	1.1	34.1–73.3
JCA group (JCA)				
age	11.2	2.7	0.5	7.0–16.2
co'–inc'/co'–go' (r)	27.4	6.6	1.1	13.1–37.0
co'–inc'/co'–go' (l)	29.5	5.3	0.9	19.4–41.1
co'–inc'/inc'–go' (r)	38.2	12.2	2.1	15.0–58.7
co'–inc'/inc'–go' (l)	42.6	11.0	1.9	24.1–69.7

Table 4. Multiple regression analysis. $Y = a + b_1JCA/N + b_2JCA/PN$† to test differences in the condylar ratio of the normal, postnormal, and JCA group. The dependent variables (Y) are co–inc′/co′–go′% and co′–inc′/inc′–go′%. Independent variables (x) are JCA/N‡ and JCA/PN‡. The variables sex, age, N/PN were excluded from the equation as no differences were found in the values measured

Y	JCA/N	JCA/PN	R^2§
co′–inc′/co′–go′ (r)	−7.4***	−5.3***	0.23***
co′–inc′/co′–go′ (l)	−4.9***	−3.0**	0.14***
co′–inc′/inc′–go′ (r)	−15.3***	−10.6***	0.21***
co′–inc′/inc′–go′ (l)	−10.6***	−5.9**	0.14***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
† a = constant; b = coefficient of regression.
‡ Concerning the independent dummy variables JCA/N and JCA/PN: 1 stands for N (normal group) and PN (postnormal group), and 2 for JCA (juvenile chronic arthritis).
§ R^2 = coefficient of determination.

Multiple regression analysis was applied to test the differences in condylar ratio and asymmetries between the three groups of patients.

Duplicate determinations were performed on 15 panoramic radiographs, giving the measurement error in terms of standard deviation, and were calculated according to the formula $S_e = \sqrt{\Sigma(a_2 - a_1)^2/2n}$.

The precision of the readings for the condylar ratios did not exceed $S_e = 2.85\%$ (co′–inc′/inc′–go′% left).

Results

In all three groups large individual variations in the condylar ratios were found. The mean values were significantly lower for the JCA group, indicating a relatively short condylar height compared with both the normal and postnormal group. The postnormal group had a slightly but not significantly smaller relative condylar height than the normal group (Tables 3 and 4).

Asymmetries were significantly more pronounced in the JCA group than in both control groups. No differences were found between the postnormal and normal group (Tables 5 and 6).

Discussion

The present methodologic study has shown that the method is applicable to clinical evaluation of the relative condylar height on the panoramic radiograph, provided the same panoramic machine is used.

Deviations in the head position did not

Table 5. Asymmetry between the right and left condyle expressed as the ratio of the smallest to the largest relative condylar height (co′–inc′/co′–go′% and co′–inc′/inc′–go′%). The measurements are based on the panoramic measurements of the three patient groups, normal (N), postnormal (PN), and juvenile chronic arthritis group (JCA), studied in the clinical part

Variable	$\bar{x}$	SD	SE	Range
N: co′–inc′/co′–go′,%	93.7	5.3	0.8	75.6–100.0
PN: co′–inc′/co′–go′,%	93.4	5.6	0.8	73.2–100.0
JCA: co′–inc′/co′–go′,%	89.5	9.9	1.7	48.8–99.1
N: co′–inc′/inc′–go′,%	90.6	7.4	1.2	65.5–100.0
PN: co′–inc′/inc′–go′,%	90.1	8.0	1.1	62.8–100.0
JCA: co′–inc′/inc′–go′,%	86.8	8.9	1.6	40.4–98.8

Table 6. Multiple regression analysis to test differences in asymmetry between the normal (N), postnormal (PN), and juvenile chronic arthritis group (JCA). Y = a + b_1JCA/N + b_2JCA/PN + b_3N/PN†. The dependent values (Y) are the smallest ratio for co'–inc'/co'–go'% or co'–inc'/inc'–go'% divided by the largest ratio, in percentage. Independent variables (x) were JCA/N‡, JCA/PN‡, N/PN§

Dep.var:Y	b_1JCA/N	b_2JCA/PN	b_3N/PN	R^2‖
co'–inc'/inc'–tgo'%	−4.3**	−3.9**	n.s.	0.06**
co'–inc'/inc'–tgo'%	−4.6*	−3.4*	n.s.	n.s.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
† a = constant; b = coefficient of regression.
‡ Concerning the independent dummy variables JCA/N and JCA/PN: 1 stands for N (normal group) or PN (postnormal group) and 2 for JCA (juvenile chronic arthritis).
§ For the dummy variable N/PN: 1 stands for N and 2 for PN.
‖ R^2 = coefficient of determination.

contribute to the variation in the measurements. Variation in mandibular morphology influences distortion and magnification in the same manner as incorrect head position. It is therefore of importance to know that these variations are of minor importance when measuring the condylar ratio.

The advantage of determining a condylar ratio instead of linear measurements is that differences in magnification can be disregarded. It also enables comparison between children independently of the individual differences in stature. Another advantage is that it enables studies of the degree of lesions of the condylar cartilage in relation to the ramus height. However, it must be kept in mind that a possible higher appositional growth in the gonion region may occur in rheumatic diseases of children.

Although age and sex distribution were not identical in the three groups studied in the clinical part, it was possible to compare them by using multiple regression analysis.

The relative condylar height in healthy children with normal occlusion is slightly greater than for those with postnormal occlusion and significantly smaller for children with JCA. This difference must be caused by the lesions of the condylar cartilage and by possible compensatory mechanisms of higher appositional growth in the gonial region, also found frequently in other studies of children with JCA (13–17, 21). The slight, but not significant, difference between the normal and postnormal group may be explained by less growth in the condylar region in the postnormal group.

Condylar asymmetries were common in the JCA group, which is in agreement with the findings of Stabrun (22) and Stabrun et al. (23), whose quantitative analysis of posterioanterior radiographs showed significantly more asymmetries in ramus height and mandibular length in JCA children, specially in those with unilateral TMJ abnormalities. Furthermore, Rönning et al. (13) and Larheim et al. (17), using qualitative assessment, found unilateral destruction of the condyle among 35–40% of JCA children with radiographically detectable condylar lesions.

In conclusion, evaluating asymmetries and condylar lesions quantitatively on panoramic radiographs provides useful information to supplement that obtained from the qualitative evaluation of condylar lesions, since panoramic machines are widely used and give small radiation dosages compared with other sophisticated methods for diagnosing condylar lesions. Further investigations of the condylar ratio in healthy individuals to establish a 'normal value' for different ages would be helpful in screening deviations from the norm quantitatively. Vertical ratios of the condyle and ramus height calculated from panoramic radiographs will also be used in studying ongoing processes longitudinally, such as the healing or progress of condylar diseases.

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