

Relation of the glenoid fossa to craniofacial morphology, studied on dry human skulls

Pertti Pirttiniemi, Tuomo Kantomaa and Olli Rönning

Institute of Dentistry, University of Oulu, Oulu, and Institute of Dentistry, University of Turku, Turku, Finland

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The purpose of this work was to compare glenoid fossa dimensions and craniofacial morphology on the basis of standard lateral roentgenograms. To overcome the difficulties encountered in making exact measurements on living subjects, 59 dry skulls were used. Eight angular measurements were taken to describe the form of the skull base, mandible, and articulating surface of the glenoid fossa, four linear measurements to describe the position of the fossa, and one to describe the size of the whole skull. A close relationship was observed between the morphology of the articulating surface of the glenoid fossa and the mandibular morphology. The skull base angulation was associated with the position of glenoid fossa in two ways. Basically, the position of the fossa is related to skull base characteristics, but the location of the articular eminence in relation to the clival plane suggests that the mandibular condyle may cause a remodeling of the eminence anteriorly when the glenoid fossa otherwise is translocated posteriorly in association with the flat skull base. □ *Articular eminence; articulating surface; mandibular morphology; skull base*

Pertti Pirttiniemi, Institute of Dentistry, University of Oulu, Aapistie 3, SF-90220 Oulu, Finland

The glenoid fossa is shallow in early childhood, and first increases rapidly in height and then more slowly through the years of adolescence (1, 2). The contour of the eminence shows great individual variation (3, 4) and seems to be correlated with facial morphology. When the articular eminence is high, the form of the face tends to be rectangular, whereas a small eminence is associated with a more triangular profile and a flat cranial base (5). The mandibular morphology has been shown to correlate with the inclination of the articulating surface of the glenoid fossa, a steep inclination being related to a rectangular shape of the mandible, whereas a shallow fossa is associated with an obtuse shape (6). A hypothesis has recently been presented according to which glenoid fossa morphology is an essential element in the growth of the mandible (6, 7). A relationship has earlier been described between the glenoid fossa position and some skeletal discrepancies and malocclusions. The glenoid fossa is located more anteriorly in class I than in class II malocclusions,

whereas in class III malocclusions the fossa is usually located more anteriorly in relation to the cranium (8).

The cranial base flexure also seems to be correlated with various malocclusions. The angular dimensions of the cranial base tend to be smaller in class III malocclusions and larger in class II malocclusions when compared with those in normal occlusions (9).

A problem with descriptions of the morphology of the glenoid fossa is the difficulty encountered in measuring glenoid fossa dimensions exactly on standard lateral roentgenograms. Tomography and other projections have been used successfully for this purpose, but these limit comparisons with cranial characteristics (3, 4).

An attempt was made here to overcome these difficulties and to examine further the shape and location of the glenoid fossa and articular eminence and their relationship to craniofacial characteristics by a method in which the configuration of the glenoid fossa is clearly defined.

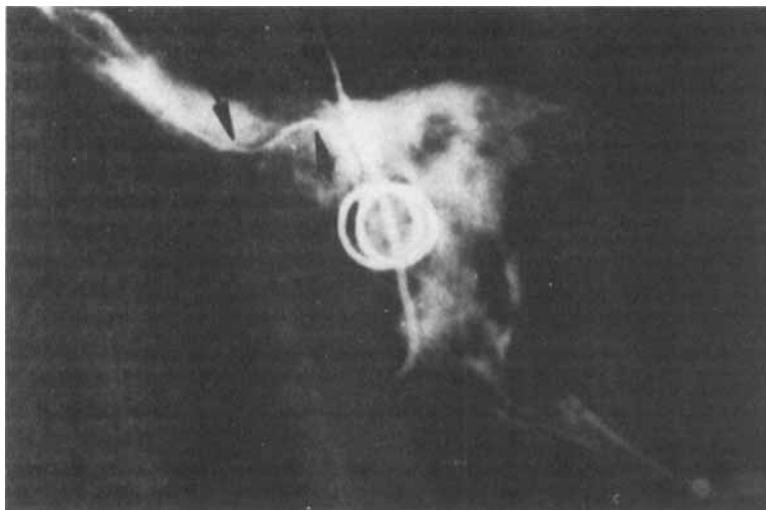


Fig. 1. The shape of the right articular surface and the clival plane is clearly visible on a lateral roentgenogram. The left fossa, which was not measured, is visible as a darker area above the right fossa.

Materials and methods

The material comprised 59 dry adult skulls, all of which had complete or nearly complete dentitions with no gross morphologic defects in structure. The contour of the glenoid fossa on the right side, which was closer to the film plane, was marked with a soft, twisted metal wire, which ran in the middle of the articular eminence in a sagittal direction (Fig. 1). The

clival plane was also marked with a metal wire.

Standard lateral roentgenograms were taken in a cephalostat after the jaws had been fixed in occlusion. The cephalometric angles and lines used are shown in Figs. 2 and 3 and explained in Table 1. All linear variables are presented relatively and are related to individual cranial length, glabella-

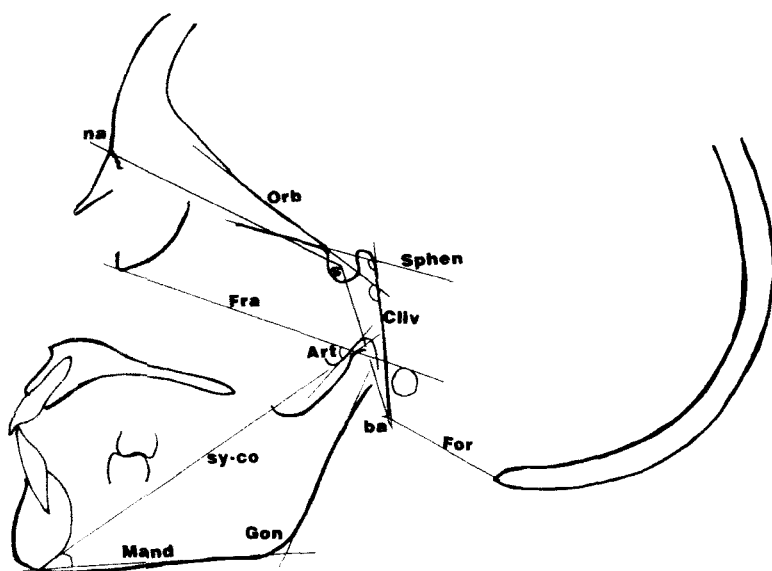


Fig. 2. Angles and lines used to describe the form of the skull base, the mandible, and the articular surface of the glenoid fossa.

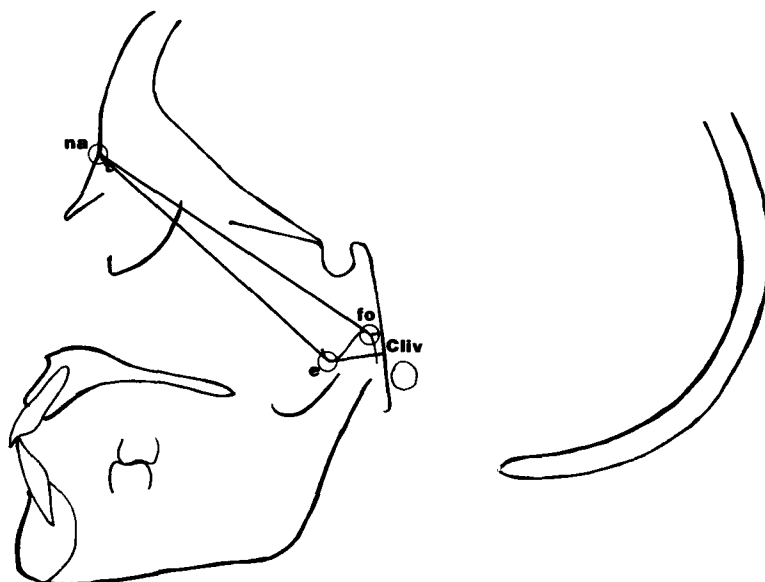


Fig. 3. Linear dimensions used to describe the position of the glenoid fossa and the articular eminence.

Table 1. Angles and linear dimension measured on the lateral skull radiographs

Angular measurements	
Art	The articulating surface angle. The angle between the articulating surface of the glenoid fossa and the Frankfort plane (3)
Gon	Gonial angle
sy-co-Mand	The angle between a line from the inferior surface of the symphysis to the anterior border of the condylar head and one from the inferior surface of the symphysis to the antegonial notch
For/Cliv	The angle between the foramen magnum plane and the clival plane
Sphen/Cliv	The angle between the tangent to the planum sphenoidale and the clival plane
Orb/Cliv	The angle between the tangent to the orbital roof and the clival plane
n-s-ba	The angle between the nasion-sella and sella-basion lines
Fra/Cliv	The angle between the Frankfort horizontal plane and the clival plane
Linear measurements	
na-fo	All linear variables are relative and related to individual cranial length, glabella-opisthocranion
na-e	Distance from the nasion tangentially to the deepest point of the glenoid fossa
fo-Cliv	Distance from the nasion tangentially to the highest point of articulating eminence
e-Cliv	Distance from the point fo to the clival plane
gl-op	Distance from the point e to the clival plane
	Glabella-opisthocranion, cranial length

Table 2. Means and deviations in the whole sample ($n = 59$) and the intraobserver methodologic error $S(i)$ in 20 duplicate recordings. S^2 denotes the variance of the whole sample

	Mean	SD	$s(i)$	$s(i)^2/S^2\%$
A1 Art	56.5	7.39	0.71	0.92
A2 For/Cliv	126.2	8.36	0.77	0.85
A3 Sphen/Cliv	116.0	8.41	0.71	0.71
A4 Orb/Cliv	135.7	8.01	0.87	1.17
A5 na-s-ba	130.3	5.79	0.87	2.26
A6 Fra/Cliv	118.5	5.94	0.79	1.54
A7 Gon	121.5	7.50	0.74	0.97
A8 sy-co-Mand	31.3	3.74	0.59	2.49
L1 na-fo	77.9	3.67	0.94	6.56
L2 e-Cliv	16.6	1.91	0.47	6.05
L3 fo-Cliv	6.5	2.47	0.27	1.20
L4 na-e	72.4	3.51	0.41	1.30
L5 gl-op	177.9	7.79	0.74	0.90

opisthocranium. Twenty roentgenograms were traced twice, to test the intraexaminer methodologic error by the formula

$$s(i) = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between repeated measurements. For statistical analysis, the nonparametric Spearman correlation was used.

Results

The means, deviations, and measurement errors of the variables used here are shown

Table 3. Spearman correlation coefficients for angular measurements describing the mandibular morphology and the angle of the articular surface

	Gon	sy-co-Mand
Art	-0.65***	0.54**
Gon		-0.84***

* $p < 0.05$; ** $p < 0.025$; *** $p < 0.001$.

in Table 2. The mandible tended to be straighter in association with a shallow glenoid fossa and more curved in the case of a deep fossa (Table 3), as the slope of the articular surface correlated negatively with the gonial angle and positively with the sy-co-Mand angle (described in Table 1).

When the points of the fossa roof (fo) and eminence (e) were projected onto the clival plane (Cliv), the distance of the eminence from the clival plane was positively correlated with the parameters of the skull base flexure. The eminence is closer to the clival plane in the case of a steep skull base than in that of a flat skull base. The distance of the fossa roof from the clival plane showed no significant correlation with the skull base parameters (Table 4).

The articular surface tended to run more horizontally when the skull base was flat and more vertically when the skull base angle parameters were small (Table 4).

The relative distance from deepest point of the glenoid fossa roof to nasion tended to be longer when the skull base flexure was

Table 4. Spearman correlation coefficients for angular (A1-A6) and linear (L1-L4) measurements describing the skull base morphology and the shape and position of the glenoid fossa

	A1	A2	A3	A4	A5	A6	L1	L2	L3
A1 Art									
A2 For/Cliv	-0.58***								
A3 Sphen/Cliv	-0.68***	0.59***							
A4 Cliv/Orb	-0.56***	0.41***	0.58***						
A5 na-s-ba	-0.67***	0.55***	0.60***	0.55***					
A6 Fra/Cliv	-0.63***	0.68***	0.69***	0.68***	0.80***				
L1 na-fo	-0.33**	0.27	0.44***	0.28*	0.43***	0.46***			
L2 e-Cliv	-0.24	0.44***	0.39**	0.42***	0.60***	0.56***	0.32*		
L3 fo-Cliv	0.19	0.06	-0.06	0.07	-0.08	0.00	-0.22	0.40**	
L4 na-e	0.10	-0.18	-0.16	-0.16	0.05	-0.06	-0.25	0.03	-0.24

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

large (Table 4), whereas the distance from the eminence to nasion showed no significant correlation with the skull base flexure.

Discussion

The intraexaminer methodological error was low relative to the total variance of the sample, as shown in Table 2. Thus the method used here to determine the shape and position of the glenoid fossa proved to be accurate, which shows the advantage of using dry skull material for this kind of investigation.

A shallow fossa was found to be related to a large gonial angle, whereas in the case of a steep articulating surface the gonial angle was small. These results support earlier conclusions concerning the close relationship between the shape of the glenoid fossa and mandibular morphology, as the direction of the condyle growth has been shown to be affected by the angle of the articulating surface of the fossa (6, 7).

The shape and position of the glenoid fossa were correlated with the form of the skull base, a flat skull base being associated with a shallow glenoid fossa when measured in terms of the direction of the articulating eminence. Furthermore, the roof of the glenoid fossa seemed to be situated slightly more posteriorly, as measured from the nasion, when the skull base was flat. This agrees with the statement of Björk (10) that the temporal bone and, with it, the glenoid fossa suffer from dorsal displacement in association with a flat cranial base. The articular eminence was, nevertheless, located more anteriorly when measured from the clival plane. This apparent disparity between the location of the roof and the eminence could be explained by earlier findings on the effect of function on the glenoid fossa (11, 13, 14).

Animal experiments in which the mandible was forced forwards and the condyle assumed a more anterior position in the fossa (12–14) have shown the fossa to remodel anteriorly and become flatter. Masticatory function was not changed in the present case, however, as evidently happened in the above animal experiments.

One of the most detailed anthropologic studies available is that of Hinton (15), in which the effect of function was investigated by using wear on the teeth as a measure of functional age. He found the fossa to deepen at first, but later to flatten along with increasing wear. A third type of investigation is represented by that of Kantomaa (16), who accelerated the posterior movement of the fossa by means of craniosynostosis without altering masticatory function. The condyle was then located more anteriorly in the fossa, which became shallower. In other words, growth of the neurocranium moved the glenoid fossa in a posterior direction. The mandible did not follow, however, as it was connected to the maxilla by elastic tissues. The experiment is obviously analogous to the situation in the present investigation, in which the posterior movement is assumed to take place as a result of growth in association with an obtuse cranial base angle (10), and it could be assumed that analogously the condyle may have been located more anteriorly in the fossa. Flattening and forward remodeling of the fossa may have happened as a result of increased pressure on the eminence. This would also be in agreement with the above results, in which the mandible was forced forwards (12–14), but is not in line with the finding of Hinton (15) that the fossa deepens at first along with increased function. Normal growth changes may have played a role in this deepening, however, as he mentions.

Hinton presented a model adapted from Frost (17) and Epker & Frost (18) for remodeling changes in the fossa in which the location of the condyle in the fossa is an important factor. When the condyle articulates in the posterior part of the slope of the eminence, the fossa remodels posteriorly and also becomes shallower, whereas when loaded on the eminence, the fossa remodels anteriorly and becomes deeper. With regard to the location of the fossa, this explanation is in agreement with the findings after artificial craniosynostosis and with the present results, but the results differ with regard to the shape of the fossa. These investigations and findings after activator treatment (11, 14, 16) tend rather to indicate that when the

condyle is articulating on the eminence, the fossa will flatten. An anthropologic investigation (15), however, showed the degree of masticatory function to be different, whereas this was not changed in association with experimental craniosynostosis, but the condylar position was assumed to be changed in both cases. Hinton & McNamara (13) similarly observed a shallowing of the fossa when the mandible—and the condyle with it—was moved forwards in the monkey with intermaxillary fixation.

The location of the roof of the fossa seemed to have remained unchanged in relation to the clival plane. Apposition of bone has been reported for the roof of the fossa in animal experiments and also in humans after forcing the condyle forwards. Sahm & Witt (19), however, found that the posterior wall of the fossa did not remodel anteriorly in association with anterior dislocation in condylar fractures, whereas marked changes in the eminence were observed, in accordance with the present findings. Thus it seems possible that the location of the posterior wall is related to morphologic factors, whereas the eminence is more under functional influence.

It may be concluded that the location of the glenoid fossa is basically related to the skull base characteristics but that its articular eminence in particular is affected by function. The findings indicate that forward remodeling of the eminence may take place even during normal growth when the cranial base angle is flat. It is significant, however, that although the events described here represent, according to earlier experimental findings, a cause-and-effect relation between the structures involved, there is also probably a reciprocal interaction.

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