

Relation of glenoid fossa morphology to mandibulofacial asymmetry, studied in dry human Lapp skulls

Pertti Pirttiniemi and Tuomo Kantomaa

Institute of Dentistry, University of Oulu, Oulu, Finland

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Asymmetry in the shape and location of the temporomandibular joint and its associations with mandibulofacial asymmetry were studied in 40 Lapp skulls by a method in which the configuration of the fossa is clearly defined. The results show a general directional temporomandibular asymmetry. The glenoid fossa on the right was on average more laterally and distally placed than on the left when studied in the axial view. The mandible was more often longer on the left than on the right in the frontal view. The temporomandibular asymmetry found here was associated with skull base characteristics and left-right differences in mandibular length. The basic reason for the asymmetric relationships may lie in the reciprocal interaction between the developmental aspects of the skull base and impaired directional function. □ *Articular surface; asymmetry mandible*

Pertti Pirttiniemi, Institute of Dentistry, University of Oulu, Aapistie 3, 90220 Oulu 22, Finland

The articular eminence of the glenoid fossa develops rapidly after birth and increases in height during first years of life (1, 2). Once the contour of the articular surface has attained its final form during the second decade, the eminence, like the whole temporomandibular joint (TMJ), is prone to remodeling changes throughout the subject's life (3-5).

The shape and location of the articular surface of the glenoid fossa have been widely studied in humans, and a great deal of research at an experimental level has also been carried out with animals. The direction of the articular surface has been shown to vary greatly, and a very close association has been established between the clinical condyle path and the anatomic shape of the articular surface (6, 7).

The mandibular morphology has been shown to be associated with the direction of the articular eminence, so that the mandible tends to be more angulated in the case of a steep articular surface but straighter in shape

in the case of a shallow fossa (8, 9). An analogous association has been found between facial form and the height of the articular eminence in children (10).

It has been shown lately that an experimentally induced change in the direction of the articular surface alters the mandibular growth direction in the growing rabbit (11). Many studies have been done on facial asymmetry in general, and they have demonstrated that a left-sided dominance is a common feature (12-14).

Associations between bilateral articular surface characteristics and mandibulofacial asymmetry have not so far been studied in subjects with a normal occlusion, although a close association has been shown recently between directional condyle path asymmetry and mandibulofacial asymmetry in unilateral crossbite patients (15).

The aim of this study was to analyze the shape and location of the glenoid fossa and its relationship to mandibulofacial asymmetry by a method in which the configuration

and location of the glenoid fossa are clearly defined, and errors due to head positioning are eliminated.

Materials and methods

The material comprised 40 dry adult skulls, 21 male and 19 female, all of which had complete or nearly complete dentitions with no gross morphologic defects in structure. The skulls belong to the largest collection of Lapp skulls, at the University of Helsinki, Finland. According to Koski (16), the individuals had been buried in the early part of the 19th century and represent a uniform racial group.

The contour of the right and left glenoid fossa and the articular eminence was marked with a soft metal wire that ran in a sagittal direction through the deepest point of the fossa in the middle of the articular eminence. The points consisting the incisive foramen, mental spine, opisthion, bilateral foramen spinosum, mandibular foramen, and mental foramen, and antegonial notches were identified with metal markers. The jaws were fixed in occlusion, and lateral roentgenograms were taken in a cephalostat to show the configuration of the left and right articular

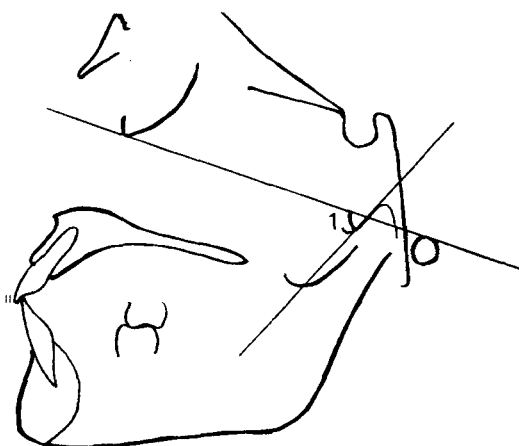


Fig. 1. The bilateral variable measured on the lateral plane roentgenographs. 1. Art = the articular surface angle. The angle between the articular surface of the left and right glenoid fossa and the Frankfort plane (Ricketts, 1950).

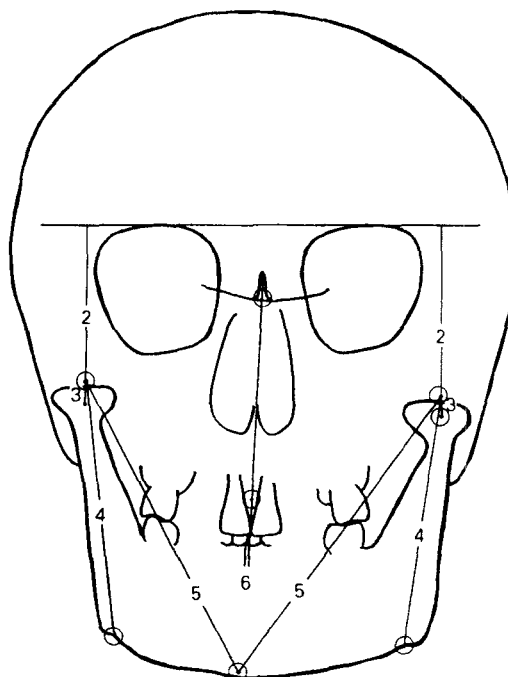


Fig. 2. The bilateral variables measured on the frontal plane roentgenograph. 2. fo-Orb = distance from the extreme superior point of the glenoid fossa to the orbital plane; 3. fo-e = distance from the extreme superior point of the glenoid fossa to the articular eminence; 4. fo-ag = distance from the extreme superior point of the glenoid fossa to the antegonial notch; 5. fo-me = distance from the extreme superior point of the fossa to the mental spine; and 6. midline = distance from the lower alveolar midline to the line that intersects the lowest midpoint of the crista galli and incisal foramen.

surface. The skulls were then roentgenographed in axial and frontal projections in the same cephalostat. The film-focus distance was in all projections 190 cm, the linear enlargement being 5.5%. No correction was made for the enlargement in the results. The cephalometric angular and linear variables are shown in Figs. 1-3. All the measurements were done twice, to test the intraexaminer methodologic error by the formula

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

where d is the difference between the repeated measurements.

The material used in the study was divided

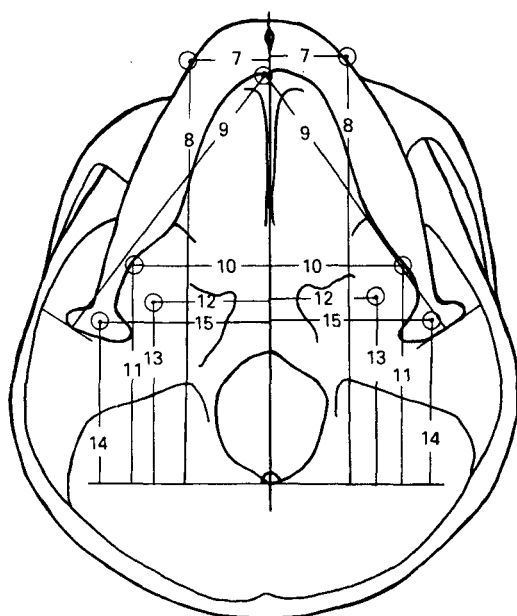


Fig. 3. Bilateral variables in the axial plane. The sagittal reference line passes through the incisal foramen and the point opisthion. The transversal reference line is perpendicular to the sagittal reference line and passes through the point opisthion. 7. for ment trans = distance from the mental foramen to the sagittal reference line; 8. for ment sag = distance from the mental foramen to the transversal reference line; 9. me-co = distance from the mental spine to the perpendicular tangent to the distolateral margin of the condyle; 10. for mand trans = distance from the mandibular foramen to the sagittal reference line; 11. for mand sag = distance from the mandibular foramen to the transversal reference line; 12. for spin trans = distance from the foramen spinosum to the sagittal reference line; 13. for spin sag = distance from the foramen spinosum to the transversal reference line; 14. fo sag = distance from the extreme superior point of the glenoid fossa to the transversal reference line; and 15. fo trans = distance from the extreme superior point of the glenoid fossa to the sagittal reference line.

in accordance with the grading of Seward (17) into three groups, and the possible effect of the tooth wear on the articular surface morphology could be estimated.

The normality of the distribution of the data was tested before the statistical analysis. The paired *t* test, the *t* test for independent samples, Pearson's correlation, the Kruskal-Wallis test, and an analysis of multiple linear regression were used for the statistical analysis proper.

Results

The intraexaminer error, *s(i)*, measured in terms of reproducibility, ranged from 0.1 to 0.3 mm in the linear measurements and was 0.7° in the angular measurements. The variance of error was less than 2% of the total variance of the sample with all the measured variables.

The only significant difference between the sexes was in the height of the articular surface (variable 3), which was bilaterally higher in males than in females (*p* < 0.05, *t* test).

The slope of the articular surface (variable 1, Table 1) was steeper on the right than on the left, and there was a general tendency for left-side dominance in the values for the vertical variables of the facial and mandibular asymmetries (variables 2 and 4, Table 1). The distance from the most superior point of the glenoid fossa to the mental spine was in the frontal view significantly longer on the left than on the right (variable 5, Table 1).

The most superior point of the glenoid fossa on the right and the foramen spinosum on the right were on average located significantly more laterally and distally in relation to the skull base than the respective

Table 1. Bilateral craniofacial variables and left-right differences in a group of dry Lapp skulls (*n* = 40)

	Left		Right		<i>p</i> value*
	\bar{x}	SD	\bar{x}	SD	
1. Art	53.6	8.89	56.4	7.81	0.031
2. fo-orb	48.0	7.20	47.2	7.37	0.045
3. fo-e	7.2	1.53	7.3	2.00	0.092
4. fo-ag	77.6	5.08	76.5	5.69	0.035
5. fo-me	104.7	8.27	101.6	8.74	0.000
7. for ment trans	27.6	3.35	27.1	3.39	0.567
8. for ment sag	131.0	7.60	130.4	7.69	0.092
9. me-co	104.2	7.12	104.4	6.95	0.697
10. for mand trans	46.3	3.10	46.5	2.91	0.761
11. for mand sag	69.7	4.97	68.7	5.15	0.075
12. for spin trans	33.4	2.04	35.5	2.21	0.000
13. for spin sa	54.8	5.35	53.3	5.10	0.006
14. fo trans	52.8	2.12	55.3	3.34	0.000
15. fo sag	50.4	4.90	49.0	5.53	0.040

* *t* test for paired observations.

Table 2. Pearson correlation coefficients between temporomandibular and mandibulofacial asymmetries in dry skulls of Lapps (n = 40)

r/	1. Art	2. fo-Orb	3. fo-e	4. fo-ag	5. fo-me	6. midline	7. for ment trans	8. for ment sag	9. me-co	10. for ma trans	11. for ma sag	12. for spi trans	13. for spi sag	14. fo trans
1. Art	NS													
2. fo-Orb	0.44**	NS												
3. fo-e	NS	-0.46**	0.36**											
4. fo-ag	NS	-0.37*	NS	0.51***										
5. fo-me	-0.53***	NS	-0.45***	NS	NS									
6. midline	NS	NS	NS	NS	NS	NS								
7. for ment trans	NS	0.31*	-0.33*	-0.34**	-0.41**	NS	NS							
8. for ment sag	NS	NS	NS	NS	NS	NS	-0.31*	NS						
9. me-co	NS	NS	NS	NS	NS	NS	0.47**	0.41**	NS					
10. for ma trans	NS	NS	NS	NS	NS	NS	-0.43**	0.47**	NS	NS				
11. for ma sag	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			
12. for spi trans	NS	NS	NS	NS	NS	NS	NS	NS	0.43**	NS	NS	NS		
13. for spi sag	NS	NS	NS	NS	NS	NS	NS	0.36*	-0.32*	NS	0.57***	NS	NS	
14. fo trans	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.34*	NS	0.63***	NS	NS
15. fo sag	NS	NS	-0.31*	NS	NS	NS	NS	0.35*	-0.46**	NS	0.70***	NS	0.82***	NS

NS = not significant; * p < 0.05; ** p < 0.01; *** p < 0.001.

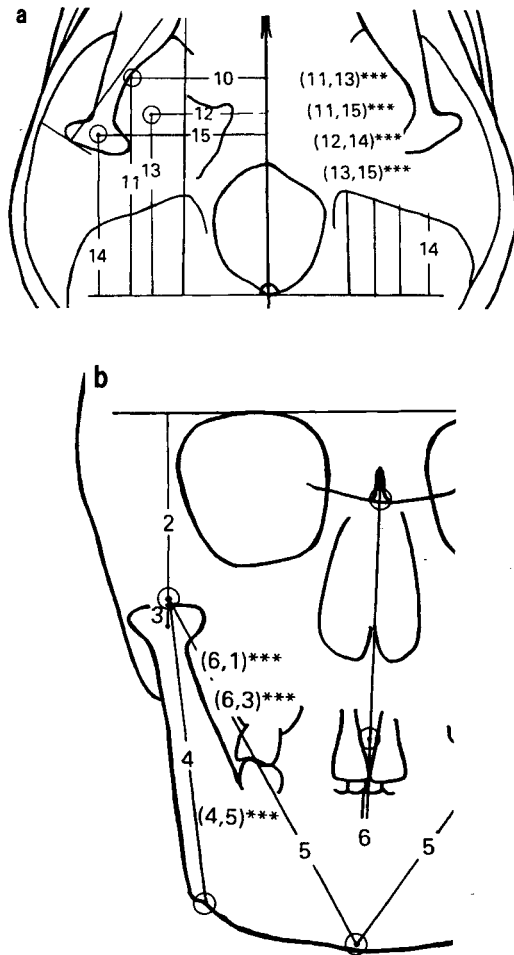


Fig. 4. The most significant intercorrelations of mandibulofacial and skull base asymmetries (shown in parentheses).

points on the left (variables 12, 13, 14, and 15, Table 1).

When the asymmetry in the location of the bilateral points of the foramen spinosum and the most superior points of the glenoid fossa was related to the mandibulofacial asymmetry, a highly significant correlation was found between the sagittal asymmetry in the foramen spinosum points (variable 13) and in the sagittal locations of the glenoid fossa and, correspondingly, in the sagittal positions of the mandibular foramina (variable 11). The asymmetry in the sagittal positions

of the left and right glenoid fossa correlated negatively with axial mandibular asymmetry (variable 9); on the side of a more distally located fossa the mandible is correspondingly unilaterally increased in length (Table 2, Fig. 4a).

Transversally, the asymmetry in the foramen spinosum points correlated significantly with the transversal asymmetry in the most superior points of the glenoid fossa and with axial mandibular asymmetry (variable 9, Table 2, Fig. 4a).

Asymmetry in the direction of slopes in the articular surfaces and in the heights of articular eminences correlated negatively with the lower alveolar midline asymmetry; the lower alveolar midline tends to deviate to the side of the steeper and higher articular surface. The difference in the heights of the left and right articular eminences showed negative correlation with asymmetry in the sagittal positions of the mandibular foramina and weak negative correlations with sagittal positions of mental foramina and glenoid fossa. Bilateral differences in distances between the orbital plane and left and right fossa correlated negatively with mandibular height asymmetry in the frontal view (Table 2, Fig. 4b).

The lower alveolar midline was found to be more often on the right than on the left ($p < 0.001$, *t* test).

The associations between asymmetry in the heights of articular eminences, on the one hand, and craniofacial and mandibular variables, on the other hand, were studied by linear multiple regression analysis. In the multiple regression analysis presented in Table 3, the regressand was asymmetry in the heights of the articular eminences of the glenoid fossa (fo-e). The significant regressors in the equation as determinators were mandibular vertical asymmetry in the frontal plane (fo-ag), deviation in the lower alveolar midline and sagittal asymmetry in the locations of the most superior points of glenoid fossa (fo sag). The coefficient of determination was high ($R^2 = 0.61$), thus showing a highly significant effect of regressors involved.

When the human dry skulls used in the study were graded for tooth wear by the

Table 3. Multiple linear regression analysis in which the regressand is the asymmetry in the heights of the left and right articular eminences and the regressors are the significant variables describing the asymmetry of the mandible and the skull base (dependent variable: fo-e)

Variable	Coefficient	Standard error estimate	<i>t</i> value	Prob > <i>t</i>
Constant	0.15	0.16	0.90	0.347
fo-ag	0.20	0.04	4.78	0.000
midline	-0.55	0.10	-5.47	0.000
fo sag	-0.15	0.03	-4.74	0.000

Coefficient of determination (R^2), 0.61; adjusted coefficient (R^2), 0.58; and coefficient of correlation, 0.78.

method of Seward (17), we found 11 dentitions with little tooth wear, 18 with moderate wear, and 11 with heavy tooth wear. When the values of the articular surface angle in these three subgroups were compared, they did not differ significantly from each other (Kruskal-Wallis test). There was, however, a tendency for a slightly deeper fossa in the more worn dentitions (Fig. 5).

In summary, the results of the present

investigation showed the articular surface to be relatively steeper on the right and the vertical variables on the left to be generally longer on the average. The glenoid fossa and the adjacent skull base point on the right were located more laterally and distally than on the left side. The measured variables of asymmetry showed various intercorrelations, the most significant relationships being found between the sagittal positions of skull base points and between asymmetries in the bilateral structures of the glenoid fossa and the mandibular midline location.

Discussion

The intraexaminer error is low as compared with the total variance of the sample, thus showing the advantage of this type of investigation. The asymmetry in the location and the height of the eminence could be studied accurately here, which would otherwise be virtually impossible in humans.

Controversial views have been presented concerning the correlation between tooth wear and the fossa depth. Dentitions with heavy tooth wear have been associated with

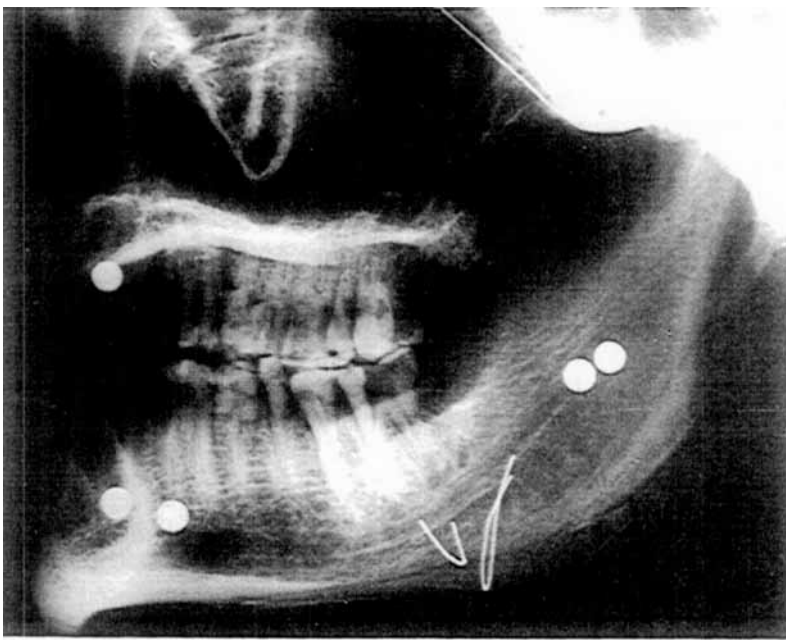


Fig. 5. A Lapp skull in the lateral view showing the metal markers and a moderately worn dentition.

shallowing of the glenoid fossa (17). Hinton (18) showed rather the fossa depth to increase relative to anterior or posterior tooth wear in Eskimos, whereas in some other aboriginals he found the correlation to be the opposite. This evident difference in the results is further discussed by Richards (19), who reminds us of the possibility that pathologic specimens may also have been included in the anthropologic examinations.

The possible effect of tooth wear on the articular surface morphology was tested in the present skull material. The rate of the tooth wear has been considered, on the other hand, to cause least bias when estimating the skeletal age of an individual (20). A slight tendency for a deepening of the fossa was noticed in most worn dentitions here. In this respect the tendency is in line with the findings of Richards (19), who reports a minor deepening of the fossa along with the tooth wear.

The results are in line with most earlier observations concerning normally occurring facial asymmetry in the frontal plane. There is, however, a controversy in earlier reports of normally occurring facial asymmetry. Most of the studies show a left-side dominance (12–14). In their cephalometric study, however, Shah & Joshi (21) found the right lower facial area to be generally larger. This could be explained by the results of this study, in which most of the vertical variables show left-side dominance, whereas the glenoid fossa on the right was positioned significantly more laterally than on the left.

Most cephalometric investigations of facial asymmetry are based on comparative measurements of the right and left sides separated by a midline, but these measurements are sensitive to errors due to head positioning in the cephalostat (22). Errors due to variation in the position of the outer ear are eliminated when a bony landmark is used for the positioning purposes, but there still remains the possibility of anatomic asymmetric variation in the bilateral temporal bones. Because the analysis here in the frontal plane is based mainly on vertical variables, the errors mentioned above are eliminated when the variables of the left and right sides are compared, as these are in

practice independent of slight variations in head positioning.

Little research has been done into bilateral differences in the condylar path, but an asymmetric tendency in the clinical condylar path has been reported in crossbite patients, and this left–right difference was found to be correspondingly smaller in cases of corrected crossbite (15). This phenomenon may result from adaptation to function, as in crossbite patients the condyle lies more anteriorly on the articular surface on the contralateral side than on the crossbite side (23, 24).

The normally occurring asymmetry found here in the condylar path and also seen in mandibular morphology might partly be due to impaired function. Right–side preference in chewing movements has been reported in cases of normal occlusion (21), and this right–side preference in chewing movements has been shown to be independent of maximal biting forces (25, 26).

There may also be other factors involved in the development of normally occurring asymmetry in condylar paths and the mandibulofacial region than the unilaterally directed function.

During growth the temporal bone grows posteriorly, and, according to Björk (27), the glenoid fossa follows it. This is also seen in the present results, as asymmetry in the skull base shows a close correlation with asymmetry in the positions of the fossa. The asymmetry in the shape and positions of the glenoid fossa are, according to present results, partly related to skull base characteristics. The skull base and the temporal bones as a part of it have been found to have normal asymmetric variation, which is directional in nature, the right being longer than the left one (28, 29). This is in line with the anatomy of the brain, in which asymmetry, particularly in temporal regions, is a fundamental pattern, the right hemisphere developing earlier and usually becoming sagittally longer (30).

Even so, the temporal part of the TMJ is under the influence of remodeling forces throughout life, as shown in human cadavers (1, 3). This remodeling is characterized by regressive changes in the articular eminence and progressive remodeling on the upper

posterior slope of the articular eminence. These changes could also explain the close association between midline asymmetry and the bilateral difference in the heights of articular eminences and direction of articular surfaces.

It is interesting that there are earlier reports claiming that the occlusal asymmetry has a directional character (15, 31). The mandibular alveolar midline was found here to be more on the right than on the left in the frontal plane, a finding that is in line with earlier results pointing to a tendency for a more postnormal occlusion on the right (31) and, respectively, a longer mandible on the left (32). This phenomenon could be related to the asymmetry in the condylar paths. As the articular surface is steeper on the right, or becomes steeper in relation to the left one, the direction of mandibular growth on the right favors a more postnormal tendency in occlusion.

In conclusion, within the limits of the present sample, the results show a directional temporomandibular asymmetry in which left-right differences in the skull base correlate with the sagittal position of the glenoid fossa and the mandibular alveolar midline asymmetry is associated with bilateral differences in the heights of the articular eminences and the direction of the articular surfaces. The basic reason for these general directional asymmetric relationships may, on the basis of results of earlier clinical and experimental studies, be the directionally impaired function and an asymmetric tendency in the skull base development.

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References

1. Wright DM, Moffett BC. The postnatal development of the human temporomandibular joint. *Am J Anat* 1974;41:235–50.
2. Nickel JC, McLachlan KR, Smith DM. Eminence development of the postnatal human temporomandibular joint. *J Dent Res* 1988;67:896–902.
3. Thilander B, Carlsson GE, Ingervall B. Postnatal development of the human temporomandibular joint. I. A histological study. *Acta Odontol Scand* 1976;34:117–26.
4. Hinton RJ. Changes in articular eminence morphology with dental function. *Am J Phys Anthropol* 1981;54:439–55.
5. Mongini F. Influence of function on temporomandibular joint. Remodeling and degenerative disease. Symposium on temporomandibular joint dysfunction and treatment. *Dental Clin North Am* 1983;27:479–94.
6. Corbett NE, DeVincenzo JP, Huffer RA, Shryock EF. The relation of the condylar path to the articular eminence in mandibular protrusion. *Angle Orthod* 1971;41:286–92.
7. Widman DJ. Functional and morphologic considerations of the articular eminence. *Angle Orthod* 1988;58:221–36.
8. Kantomaa T. The relation between mandibular configuration and the shape of the glenoid fossa in the human. *Eur J Orthod* 1989;11:77–81.
9. Pirttiniemi P, Kantomaa T, Rönning O. Relation of the glenoid fossa to craniofacial morphology, studied on dry human skulls. *Acta Odontol Scand* 1990;48:359–64.
10. Ingervall B. Relation between height of the articular tubercle of the temporomandibular joint and facial morphology. *Angle Orthod* 1974;44:15–24.
11. Kantomaa T. The shape of glenoid fossa affects the morphology of the mandible. *Eur J Orthod* 1988;10:2:49–54.
12. Letzer GM, Kronman JH. A posteroanterior cephalometric evaluation of craniofacial asymmetry. *Angle Orthod* 1967;37:205–11.
13. Vig PS, Hewitt AB. Asymmetry of the human facial skeleton. *Angle Orthod* 1975;45:125–29.
14. Chebib FRS, Chamma AM. Indices of craniofacial asymmetry. *Angle Orthod* 1981;51:214–26.
15. Pirttiniemi P, Kantomaa T, Lahtela P. Relationship between craniofacial and condyle path asymmetry in unilateral cross-bite patients. *Eur J Orthod* 1990;12:408–13.
16. Koski K. A study on the alveolar arches of the Lapps [thesis]. Helsinki: Department of Anatomy, University of Helsinki, 1948:21–2.
17. Seward FS. Tooth attrition and the temporomandibular joint. *Angle Orthod* 1976;46:162–70.
18. Hinton RJ. Changes in articular eminence morphology with dental function. *Am J Phys Anthropol* 1981;54:439–55.
19. Richards LC. Temporomandibular joint morphology in two Australian aboriginal populations. *J Dent Res* 1987;66:1602–7.
20. Meindl RS, Lovejoy CO, Mensforth RP. Skeletal age at death: accuracy of determination and implications for human demography. *Hum Biol* 1983;55:73–87.
21. Shah SM, Joshi MR. An assessment of asymmetry in the normal craniofacial complex. *Angle Orthod* 1978;48:141–8.
22. Cook JT. Asymmetry of the cranio-facial skeleton. *Br J Orthod* 1980;7:33–8.

23. Myers DR, Barnie JT, Bell RA, Williamson EH. Condylar position in children with functional posterior crossbites: before and after crossbite correction. *Pediatr Dent* 1980;2:190-4.
24. Pirttiniemi P, Raustia A, Kantomaa T, Pyhtinen J. Relationships of bicondylar position to occlusal asymmetry. *Eur J Orthod* 1991;13:441-5.
25. Manly RS, Shiere FR. The effect of dental deficiency on mastication and food preference. *Oral Surg* 1950;3:674-85.
26. Shiere FR, Manly RS. The effect of changing dentition on masticatory function. *J Dent Res* 1952;31:526-34.
27. Björk A. Cranial base development. A follow-up X-ray study of the individual variation in growth occurring between ages 12 and 20 years and its relation to brain case and face development. *Am J Orthod* 1955;41:195-225.
28. LeMay M. Asymmetries of the skull and handedness. *J Neurol Sci* 1977;32:243-53.
29. McManus IC. The distribution of skull asymmetry in man. *Ann Hum Biol* 1982;9:167-70.
30. Geschwind N. Cerebral lateralization. Biological mechanisms, associations, and pathology. I. A hypothesis and a program for research. *Arch Neurol* 1985;42:428-59.
31. Leighton BC, Feasby WH. Factors influencing the development of molar occlusion: a longitudinal study. *Br J Orthod* 1988;15:99-103.
32. Williamson EH, Simmons MD. Mandibular asymmetry and its relation to pain dysfunction. *Am J Orthod* 1979;76:612-7.

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