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Morphological differences in the temporomandibular joints in asymmetrical prognathism patients

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Dates:
Accepted 3 March 2006

To cite this article:
Orthod Craniofac Res **9**, 2006; 71–76
Kawakami M, Yamamoto K, Inoue M, Kawakami T, Fujimoto M, Kirita T:
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Structured Abstract

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Objective – To investigate the morphology of the temporomandibular joints (TMJ) in skeletal asymmetry with prognathism.

Design – Three-group observational clinical study.

Setting and Sample Population – University setting. Thirty-five patients undergoing orthognathic surgery without signs and symptoms of TMJ disorder were assigned to three groups (right deviation, n = 11; left deviation, n = 14; and non-deviation; n = 10) based on anteroposterior cephalometric analysis.

Outcome Measure – Positional and morphological differences of the TMJs were evaluated using a total of 70 bilateral sagittal TMJ magnetic resonance images.

Results – In both the right and left deviation groups, the TMJ on the deviated side showed a significantly steeper eminence than that on the non-deviated side ($p < 0.05$). The anterior joint space was narrower on the deviated side than on the non-deviated side whereas the posterior joint space did not differ markedly, indicating an anterior position of the condyle in the glenoid fossa of the TMJ on the deviated side. Disk displacement comparisons revealed no significant differences between left and right sides in the symmetry or asymmetry group.

Conclusion – Asymmetrical prognathism patients exhibit significant morphological differences between the right and left TMJs concerning the slope of the articular eminence, which correspond to facial asymmetry.

Key words: facial asymmetry; magnetic resonance imaging; mandibular condyle; prognathism; temporomandibular joint

Introduction

Mandibular prognathism patients can have an asymmetrical face with a mandible that deviates to either the left or right side with no obvious facial or dental anomalies (1), which often results from unbalanced lateral and vertical growth of the craniofacial structures. The structural asymmetry of the craniofacial complex in adults is considered to be a functional adaptation to mandibular displacement (2). Further, it has been hypothesized that mandibular displacement can change the modeling process of the temporomandibular joint (TMJ) and gradually leads to permanent structural asymmetry in a growing person (3). In addition, mandibular asymmetry does not consist of only left–right size differences between the maxilla and mandible but also shows morphological differences in the TMJ.

Once mandibular growth is completed, prognathism is generally treated by orthodontic treatment followed by surgical correction of the mandible, such as a sagittal split osteotomy or vertical ramus osteotomy, which can change the postoperative condylar position. It has been shown that temporomandibular joint disorder (TMD) and disk dislocation emerge postoperatively, caused by a dorsal proximal segment position related to manual positioning procedures (4). Before planning treatment of patients with mandibular prognathism with asymmetry, it is necessary to understand the difference in TMJ morphology between the deviated and non-deviated sides. Details of the morphology of TMJ and its relationship to skeletal asymmetry have not been extensively reported.

Facial asymmetry caused by mandibular lateral displacement is a relatively common problem in patients with an internal derangement of the TMJ (5). Left–right differences in the morphology of TMJ with mandibular asymmetry may represent anatomic disorders that predispose to joint sounds and TMJ problems pre- and postoperatively (6). Trpkova *et al.* (7) studied females with bilateral TMJ internal derangements and found significantly greater asymmetry in the vertical position, while the other craniofacial regions did not show any differences in the degree of asymmetry.

The purpose of the present study was to investigate the relationship between skeletal facial laterality and TMJ morphology in patients with asymmetrical prognathism prior to surgical orthodontic treatment.

Subjects and methods

Subjects

We studied 35 Japanese patients (10 men, 25 women; mean age 24 years 5 months, range 16 years 9 months to 38 years 4 months), who visited our university hospital from 2001 to 2005. All had been diagnosed with mandibular prognathism and were scheduled for combined surgical orthodontic treatment. None of the subjects had congenital craniofacial anomalies or missing teeth. TMJ function was evaluated in each patient based on TMJ pain, joint sounds, and mouth opening limitations, and only clinically symptom-free subjects were included in the study.

Anteroposterior cephalometric analysis

Anteroposterior cephalograms of each patient were taken prior to surgery in centric occlusion at a magnification ratio of 1:1 and traced twice by one of the authors. Landmarks were identified using the method recommended by Sassouni (8) (Fig. 1). The perpendicular distance from the facial midline to each landmark was measured to an accuracy of 0.5 mm. Deviation of the menton (Me) from the facial midline on the frontal plane of more than 3 mm was considered

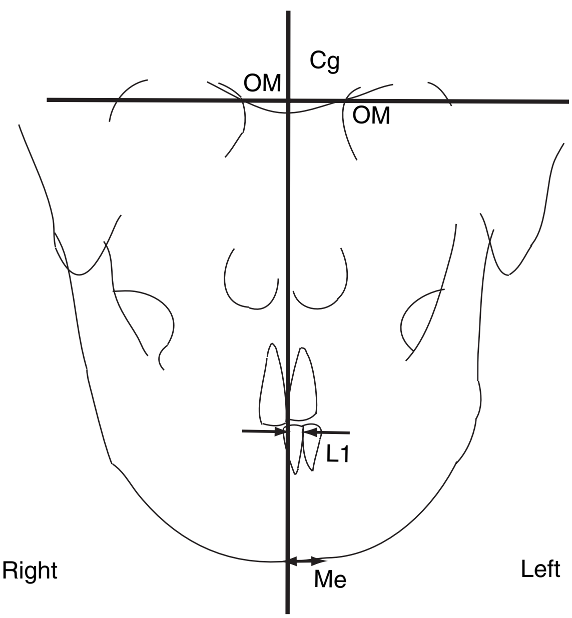

Fig. 1. Anteroposterior cephalometric landmarks, reference plane and asymmetry measurements. The facial midline was constructed as a line passing through the crista galli (Cg), perpendicular to the intersections of the cranial base line at the orbital margin (OM). L1: midpoint of the lower incisor edge, Me: menton.

asymmetric. Based on the results, all subjects were assigned to two of the asymmetry groups (left deviation, n = 14; right deviation, n = 11) or the symmetry group (no deviation, n = 10).

Magnetic resonance imaging

Magnetic resonance images (MR images) were made using a 1.5-T unit (Signa MR/I scanner; GE Medical systems, Milwaukee, WI, USA) with bilateral receiver surface coils 12 cm in diameter. Seventy sets of MR images of each TMJ were obtained. Sequential bilateral images were taken with a closed mouth and the teeth in centric occlusion. Initially, axial scout images were obtained at the level of the TMJ to identify exact mid-condylar sections. The head of the patient was placed so that the Frankfurt plane was perpendicular to the plane of the table, in order to obtain a consistent orientation of sagittal images after which MR images were taken perpendicular (sagittal images) and parallel (coronal images) to the horizontal long axis of the mandibular condyle. A spin echo technique [repetition time (TR) = 600 ms and echo time (TE) = 10.5 ms] was used and six contiguous 3-mm thick parasagittal images with a field of view of 12 cm were obtained.

Measurements were made twice on the sagittal MR images passing through the center of the condyle, as shown in Fig. 2. Linear and angular measurements were performed for the right and left TMJ on the images to evaluate the articular eminence of the joint, disk position associated with the condyle, and condylar position associated with the glenoid fossa (Gf), according to the methods of Cohlmia *et al.* (9) and Gökalp (10). Briefly, the eminence slope was defined as the angle between the horizontal plane and a tangent drawn from the deepest point of the Gf to the slope of the anterior eminence (A). Thereafter, lines were drawn from the geometrical center of the condyle head (Cc) to Gf and from the Cc to the posterior margin of the posterior band of the disk, after which the angle between these lines was measured (B). When the posterior margin of the disk was located anterior to the Cc–Gf line, a positive value was assigned. The narrowest anterior (C) and posterior (D) distances between the surface of the condyle and the inner face of the Gf were also measured, and the condylar position within the Gf [fossa ratio (%)] was expressed as a percentage of the anterior and posterior displacements from absolute concentricity according to the following formula: $(D - C)/(D + C) \times 100$. A positive value indicated that the condyle had an anterior position in the Gf, while a negative value indicated that it had a posterior position.

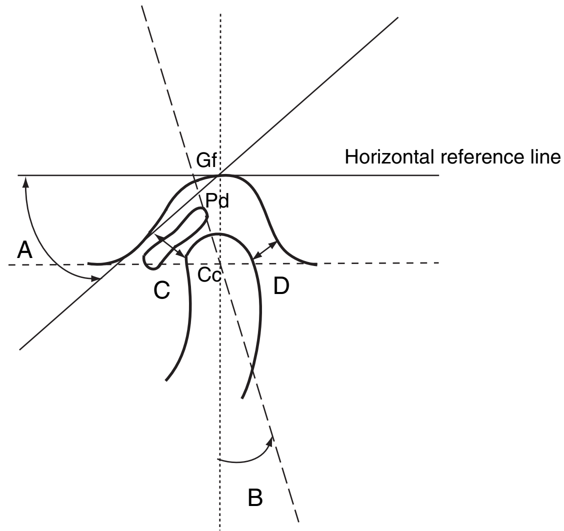

Fig. 2. Angular and linear measurements of the temporomandibular joint on MR images. Gf: deepest point of the roof of the glenoid fossa; Cc: center of the condylar head; Pd: posterior edge of the disk; Horizontal reference line: tangent to the Gf and parallel to the horizontal plane on the MR image. A: Eminence slope angle between the horizontal reference line and a line drawn tangent from the Gf to the anterior slope of the glenoid fossa. B: Disk posterior angle between the line from the Gf to the Cc and the line from Pd to Cc. C: Anterior joint space. D: Posterior joint space.

All measurements were performed by one investigator (MK). Measurements were taken twice with a minimum interval of 1 month to determine intra-examiner repeatability of the landmark identification and measurement findings.

Statistical analysis

Right and left TMJ variables were compared using a paired *t*-test or the Wilcoxon signed-rank test with Microsoft Excel XP for Windows. $p < 0.05$ was considered to be significant.

Results

All angular and linear variables showed a coefficient of reliability between 0.910 and 0.949, thus the errors were considered to be negligible (Table 1).

Anteroposterior cephalometric measurements initially divided the patients into those with symmetry (no

Table 1. **Reliability of the measurements**

	Correlation coefficient (*r*)	Sample (n)
Eminence slope	0.949	35
Disk position	0.948	35
Anterior space	0.910	35
Posterior space	0.912	35

deviation group, n = 10) and those with asymmetry (n = 25). Those with asymmetry were divided into the left deviation group (distance from the facial midline 3.5 ± 1.0 mm at L1 and 4.9 ± 2.0 mm at Me, n = 14) and the right deviation group (distance from facial midline 4.3 ± 2.3 mm at L1 and 6.5 ± 3.2 mm at Me, n = 11). The amount of jaw deviation did not differ significantly between the left and right deviation groups.

Temporomandibular joint sounds (clicking, crepitus) were recognized in 14 of 50 joints in the asymmetry group and 4 of 20 joints in the no deviation group. The distribution of occurrence of TMJ sounds did not differ significantly between the deviation and no deviation patients.

The anterior steepness of the articular eminence differed significantly between the right and left TMJ (Fig. 3, Table 2). The left eminence was steeper (36.7 ± 8.2°) than the right eminence (30.0 ± 5.9°) in the left deviation group, while the right eminence was steeper (36.5 ± 7.6°) than the left eminence (31.2 ± 7.2°) in the right deviation group ($p < 0.05$). Further, the deviated side showed a steeper eminence angle to the horizontal reference plane. There was no significant difference in the bilateral eminence steepness between the two sides in the no deviation group.

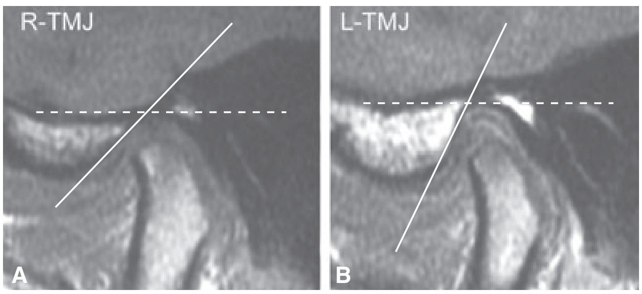

Fig. 3. Parasagittal images in a patient with left deviation showing differences in anterior eminence slope of the temporomandibular joint. (A) Right side. (B) Left side. Dotted line: horizontal reference line; continuous line: eminence slope.

The anterior joint space of the TMJ differed significantly between the right and left sides. In the left deviation group, the joint space was significantly narrower on the left side (2.2 ± 0.5 mm) than that on the right side (2.6 ± 0.7 mm). Similarly, the joint space was narrower on the right side (2.1 ± 0.6 mm) than on the left side (2.5 ± 0.7 mm) in the right deviation group ($p < 0.05$). The posterior joint space did not differ significantly between the left and right sides in either of the asymmetry groups or the no deviation group. Thus, the deviated side showed a narrower anterior space between the eminence and the condyle compared with the non-deviated side.

Comparisons of the amount of disk displacement revealed no significant differences between the left and right sides in any of the three groups. The fossa ratio in the asymmetry groups was lower on the deviated side than on the non-deviated side, though the difference was not significant. In the non-deviation group, there was no significant difference between the fossa ratios on the left and right sides. These results indicated that the anterior joint space was narrower on the deviated side than that on the non-deviated side in patients with asymmetry.

Discussion

It is thought that patients with mandibular prognathism often have a condyle located in the anterior part of the Gf (9). A previous assessment of patients with skeletal and dental asymmetry revealed that the mandible is rotated in such a way as to allow the condyle on the crossbite side to be positioned relatively posterior in comparison with the contralateral side (11). We found that jaw asymmetry was associated with significant differences in TMJ morphology in the patients, as the deviated side had a steeper slope of the eminence and a narrower anterior space of the joint than the contralateral side. These findings were clearly observed in both right and left deviation cases. However, there was no correlation between anterior disk displacement and direction of jaw deviation.

In an asymmetrical mandible, the condyle on the contralateral side traces a shallower pathway during opening and protrusive mandibular movements whereas the condyle of the shifted side demonstrates axial movement (12). A shallower angle of the condylar

Table 2. **Bilateral TMJ measurements and statistical comparison**

	Asymmetry group (n = 25)										Symmetry group (n = 10)				
	Left deviation (n = 14)					Right deviation (n = 11)									
	Left TMJ		Right TMJ			Left TMJ		Right TMJ			Left TMJ		Right TMJ		
Variables	Mean	SD	Mean	SD	*p*-value	Mean	SD	Mean	SD	*p*-value	Mean	SD	Mean	SD	*p*-value
Eminence slope angle (°)	36.7	8.2	30.0	6.9	*	31.2	7.2	36.5	7.6	*	32.1	4.9	30.8	7.2	NS
Disk position angle (°)	1.0	13.8	0.4	20.5	NS	–0.5	16.2	7.2	17.0	NS	–0.7	14.1	–0.6	16.1	NS
Anterior joint space (mm)	2.2	0.5	2.6	0.7	*	2.5	0.7	2.1	0.6	*	2.6	0.7	2.6	0.7	NS
Posterior joint space (mm)	2.1	0.7	2.0	0.7	NS	2.3	0.6	2.3	0.4	NS	2.7	0.7	2.7	0.5	NS
Condylar position (%)	–5.4	14.0	–13.8	21.3	NS	–3.2	15.4	6.2	12.9	NS	0.5	23.3	3.1	19.7	NS

TMJ, temporomandibular joint; SD, standard deviation; NS, not significant.
*$p < 0.05$.

pathway on the contralateral side is suggested to be the result of remodeling or degenerative changes of the bone surface (13,14). These condylar pathways are also required for bony adaptation of TMJ morphology on the deviated side which results in a steeper eminence. Significant angular differences in TMJ eminence may be derived from adaptation to asymmetrical loading of the TMJ. Numerical models for the TMJ provide evidence that the articular eminence develops specifically to optimize the direction of condylar loading and facilitates the minimization of joint loads. Asymmetrical jaw function alters the force dynamics within the joint, which stimulates an adaptive response and results in altered osseous contours (15,16). Taken together, we consider that the asymmetrical force dynamics in the joint could be responsible for the development of different morphologies between the right and left TMJ.

Skeletal mandibular asymmetry results from a growth disharmony of mandibular size, shape and position with respect to the maxilla. Indeed facial asymmetry can result from other reasons, such as trauma with fracture, tumor, and condylar or hemimandibular hypertrophy. The subjects in our study were selected to eliminate the influence of unilateral condylar hyperplasia on facial asymmetry. We analyzed patients with either right or left jaw deviation and found that the anterior joint space within the Gf was narrower on the deviated side than on the contralateral side, regardless of right side or left side deviation. The fossa ratios did not differ between the right and left TMJ in the asymmetrical cases. These observations were consistent with a report that the joint space ratio in asymmetrical Angle Class III patients did not differ between the deviated and non-deviated sides (17). Another TMJ tomography study revealed that the relationships between the condylar positions and TMJ space on the crossbite and non-crossbite sides were similar (11). Cohlmia *et al.* concluded that asymmetry may be related to commonly occurring cranial base asymmetries (9). No difference in the fossa ratio between the right and left TMJ would result from morphological change in osseous articular surface contour of the TMJ. It is likely that the condylar positions in asymmetry patients are similar within the glenoid fossa.

Temporomandibular joint internal derangement related to condylar remodeling might develop vertical mandibular discrepancy and cause mild and moderate mandibular asymmetry (7). Subjects with TMJ internal derangement of greater severity on the unilateral side had a shorter ramus height. The unilateral shorter ramus height might reduce mandibular length on the ipsilateral side and result in displacement of the mandibular midline (18). As our asymmetric subjects did not show any symptoms, our data do not directly indicate an association between TMD and skeletal asymmetries. Gökalp *et al.* (19) found no correlation between movements of the disk–condyle assembly and the steepness of the articular eminence.

We have demonstrated asymmetrical shape of the TMJ in patients with asymmetrical mandibular prognathism. This study is a step toward objective measurement of TMJ shape by using methods that understand changes in the TMJ after asymmetric mandibular setback. Further elucidation of the relationship between the shape and symptoms of TMJ is needed.

Acknowledgement: This study was partially supported by a grants-in-aid for scientific research (15592171) from the Japan Society for the Promotion of Science.

References

1. Proffit WR, Turvey TA. Dentofacial asymmetry. In: Proffit WR, White RP, Sarver DM, editors. *Contemporary Treatment of Dentofacial Deformity*. St Louis, MO: Mosby; 2003. pp. 574–644.
2. Schmid W, Mongini F, Felisio A. A computer-based assessment of structural and displacement asymmetries of the mandible. *Am J Orthod Dentofac Orthop* 1991;**100**:19–34.
3. Nerder PH, Bakke M, Solow B. The functional shift of the mandible in unilateral posterior crossbite and the adaptation of the temporomandibular joints: a pilot study. *Eur J Orthod* 1999;**21**:155–66.
4. Landes CA, Sterz M. Proximal segment positioning in bilateral sagittal split osteotomy: Intraoperative controlled positioning by a positioning splint. *J Oral Maxillofac Surg* 2003;**61**:1423–31.
5. Inui M, Fushima K, Sato S. Facial asymmetry in temporomandibular joint disorders. *J Oral Rehabil* 1999;**26**:402–6.
6. Buranastidporn B, Hisano M, Soma K. Articular disk displacement in mandibular asymmetry patients. *J Med Dent Sci* 2004;**51**:75–81.
7. Trpkova B, Major P, Nebbe B, Prasad N. Craniofacial asymmetry and temporomandibular joint internal derangement in female adolescents: a posterioranterior cephalometric study. *Angle Orthod* 2000;**70**:81–8.
8. Sassouni V. Position of the maxillary first permanent molar in the cephalofacial complex. *Am J Orthod* 1957;**43**:477–510.
9. Cohlmia JT, Ghosh J, Sinha PK, Nanda RS, Currier GF. Tomographic assessment of temporomandibular joints in patients with malocclusion. *Angle Orthod* 1996;**66**:27–35.
10. Gökalp H. Magnetic resonance imaging assessment of positional relationship between the disk and condyle in asymptomatic young adult mandibular prognathism. *Angle Orthod* 2003;**73**:550–5.
11. O'Byrn BL, Sadowsky C, Schneider B, BeGole EA. An evaluation of mandibular asymmetry in adults with unilateral posterior crossbite. *Am J Orthod Dentofac Orthop* 1995;**107**:394–400.
12. Sülün T, Cemgil T, Rammelsberg P, Jäger L, Gernet W. Morphology of the mandibular fossa and inclination of the articular eminence in patients with internal derangement and in symptom-free volunteers. *Oral Surg Oral Med Oral Path Oral Radiol Endod* 2001;**92**:98–107.
13. Ren YF, Isberg A, Westesson PL. Steepness of the articular eminence in the temporomandibular joint. Tomographic comparisons between asymptomatic volunteers with normal disk position and patients with disk displacement. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995;**80**:258–66.
14. Yamada K, Tsuruta A, Hanada K, Hayashi T. Morphology of the articular eminence in temporomandibular joints and condylar bone change. *J Oral Rehabil* 2004;**31**:438–44.
15. Nickel JC, McLachlan KR, Smith DM. A theoretical model of loading and eminence development of the postnatal human temporomandibular joint. *J Dent Res* 1988;**67**:903–10.
16. Palla S, Gallo LM, Gossi D. Dynamic stereometry of the temporomandibular joint. *Orthod Craniofac Res* 2003;**6**(Suppl. 1):37–47.
17. Ueki K, Nakagawa K, Takatsuka S, Shimada M, Marukawa K, Takazakura D et al. Temporomandibular joint morphology and disk position in skeletal Class III patients. *J Craniomaxillofac Surg* 2000;**28**:362–8.
18. Ann SJ, Lee SP, Nahm DS. Relationship between temporomandibular joint internal derangement and facial asymmetry in women. *Am J Orthod Dentofacial Orthop* 2005;**128**:583–91.
19. Gökalp H, Türkkahraman H, Bzeizi N. Correlation between eminence steepness and condyle disk movements in temporomandibular joints with internal derangements on magnetic resonance imaging. *Eur J Orthod* 2001;**23**:579–84.