Original

Retrospective magnetic resonance imaging study of risk factors associated with sideways disk displacement of the temporomandibular joint

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Abstract: As part of our ongoing investigation of risk and predictive factors associated with temporomandibular disorders, we used magnetic resonance imaging (MRI) to identify risk factors for sideways disk displacement of the temporomandibular joint in 26 patients with MRI-confirmed unilateral pure sideways disk displacement (medial or lateral disk displacement) and normal positioning of the contralateral temporomandibular joint. Coronal morphologic harmonization between the condyle and fossa, angle between the axis of the ramus and condyle, and angle between the lateral pterygoid muscle (LPM) and condyle were evaluated. Only angle of the LPM related to the condyle was significantly correlated with mediolateral disk position; the angles of joints with medial, normal, and lateral disk positions were 70.2°, 66.7°, and 60.1°, respectively. These results suggest that a greater angle of the inferior head of the LPM to the axis of the condyle on axial MRI images may cause medial disk displacement, while a smaller angle may result in lateral disk displacement. (J Oral Sci 58, 29-34, 2016)

Keywords: sideways disk displacement; internal derangement; MRI; temporomandibular joint.

Introduction

Internal derangement of the temporomandibular joint (TMJ) is one of the most common temporomandibular disorders (TMDs). This condition includes disk displacement with/without reduction (1). Diagnostic criteria for TMD (DC/TMD) classify internal derangement of the TMJ as intra-articular TMD, along with degenerative joint disease and subluxation (2). A diagnosis of internal derangement without limited mouth opening and degenerative joint disease, as determined by clinical findings and patient history in accordance with DC/TMD criteria, is less sensitive than that of other types of TMD, such as pain-related TMD and subluxation (2). Thus, imaging evaluation is required for definitive diagnosis of internal derangement and degenerative joint disease of the TMJ.

Magnetic resonance imaging (MRI) is the most reliable imaging modality for evaluating internal derangement (3,4). MRI provides clear sectional images of soft and hard tissue structures and reveals intra-articular pathologies associated with internal derangement. Many studies have evaluated the relationships between clinical and MRI findings and the pathogenesis of internal derangement in relation to MRI findings (5-8). In general, sagittal slice images of the TMJ are used to evaluate TMJ disk pathologies. Some researchers have identified factors associated with anterior disk displacement of

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the TMJ (9,10). Taskaya-Yilmaz et al. (9) focused on attachment of the superior head of the lateral pterygoid muscle (LPM) and showed that type 1 attachment (where the fibers of the superior head of the LPM were attached only to the condyle) was most common in the anterior disk-displaced group. This was a fascinating finding, as it showed that the anatomic properties of muscle, bone, and disk are closely related to internal derangement.

Our previous study (10) of morphologic discrepancies between the condyle and fossa on coronal slice images showed that a discrepancy between the condyle and fossa shape may be a risk factor in the pathogenesis of anterior disk displacement. This result confirmed that the morphologies of TMJ components and morphologic harmonization are closely related to the pathogenesis of internal derangement and anterior disk displacement. In contrast, few studies have focused on sideways disk displacement and related factors. Coronal shape and morphologic harmonization of the condyle and fossa, which we investigated in a previous study (10), had no effect on sideways disk displacement, which was contrary to our expectations. However, our previous study investigated anterior disk displacement of the TMJ, and all participants had severe internal derangement of the TMJ. The mediolateral disk position is strongly affected by anterior disk position, and our previous study did not show a clear relationship between mediolateral position of the disk and morphologic harmonization between the condyle and fossa (10). Thus, anatomic harmonization and the characteristics of muscle and bone morphology are important for clinicians involved in TMD diagnosis and therapy.

The aim of the present study was to identify risk factors for sideways disk displacement of the TMJ on MRI evaluation, as part of our ongoing studies to identify risk and predictive factors related to TMD.

Materials and Methods

Patients

This retrospective study evaluated data from 26 (52 joints; 9 men and 17 women; mean age, 43.0 years) of the 1,422 patients who underwent MRI examination for TMD treatment or a checkup examination before orthodontic treatment between January 2009 and June 2015 at our institution. The inclusion criteria were as follows: unilateral sideways disk displacement without anterior disk displacement (pure medial or lateral disk placement) and normal anterior sideways disk position of the contralateral TMJ on MRI. We excluded patients with degenerative changes (such as osteophytes, surface erosions, and bone marrow changes) on one or both sides

of the TMJ, growth abnormalities (such as macrognathia, micrognathia, and facial asymmetry), or a history of facial trauma or systemic arthritis (such as rheumatoid or psoriatic arthritis and gout), and those younger than 18 years. In addition, patients with more than two continuous missing teeth were also excluded. All participants were clinically healthy and had no internal derangement based on DC/TMD criteria, but some had myalgia of the masseter and temporal muscles. The use of imaging data in this study was reviewed and approved by the Bioethics Committee at Nihon University School of Dentistry (EP2008-22) and was performed in accordance with the ethical standards established in the 2013 revision of the Declaration of Helsinki. All patients provided written informed consent.

Image acquisition

A 3.0-T MR unit (Achieva 3.0 T; Philips, Amsterdam, The Netherlands) with a head coil was used for imaging the TMJ. Proton density-weighted images (repetition time (TR) 1,800 ms, echo time (TE) 20 ms, field of view (FOV) 130 × 130 mm) of coronal and sagittal sections and T1-weighted axial images (TR 426 ms, TE 9 ms, FOV 220 × 220 mm) were scanned by 1 spin-echo sequence for image evaluation. Other imaging parameters were a matrix size of 512 × 512 and a flip angle of 90° on all image scans. Sagittal scans were set so that they were parallel to the short axis of the condylar head, and coronal scans were set so that they were parallel to the long axis of the condylar head, as described by Stehling et al. (11).

Axial images were scanned parallel to the Frankfort horizontal plane. Slice thickness was 3 mm for sagittal and coronal slice images and 5 mm for axial slice images.

Image evaluation

All MRI evaluations and measurements were performed independently by two oral and maxillofacial radiologists. Disagreements in image interpretation were resolved by consensus. For image evaluation and measurement, images of axial, sagittal, and coronal sections that sliced through the center of the condyle were used.

Disk evaluation

Before the present study, disk status, such as anteroposterior shape, was classified as normal by using the following criteria (10,12). Normal position was defined as an arrangement in which the intermediate zone of the disk was interposed between the head of the condyle and the posterior slope of the articular eminence, with the mouth closed. Normal disk shape was interpreted as biconcave or a disk of even thickness; disks with other shapes, such

Fig. 1 Mediolateral disk position in coronal slice images of right temporomandibular joints. A: normal disk position, B: medial disk displacement, C: lateral disk displacement. Mediolateral disk position on coronal slice images was assessed by using the criteria of Liedberg and Westesson (13). Arrows indicate displaced disks, which did not cover the opposite sides of the condyle pole.

Fig. 2 Measurement of Angle 1 on a representative coronal slice image. Lines A and B indicate the axes of the ramus and transversal condyle diameter, respectively. Angle 1 is defined as the angle between lines A and B.

Fig. 3 Measurement of Angle 2 on a representative axial slice image. Lines X and Y indicate the axes of the condyle and the direction of the lateral pterygoid muscle at the center of the condyle, respectively. Angle 2 is defined as the angle between lines X and Y.

as biconvex, were classified as abnormal. Regardless of the type of disk displacement and/or abnormal disk shape, all joints with disk displacement and/or abnormal shape were excluded from the analysis. Mediolateral disk position was assessed on coronal slice images by using the criteria of Liedberg and Westesson (13) (Fig. 1). In normal disk position, the disk covers the superior surface and medial and lateral poles of the condyle on a coronal slice image. In sideways disk displacement, medially and laterally displaced disks do not cover the lateral and medial poles of the condyle, respectively.

Evaluation of the shape of the condyle and fossa

Using MR images, we classified the shape of condyles and fossae on coronal sections by using a four-grade system, as in our previous study (10); condyles and

fossae were classified as convex, angled, flat, and “other” (i.e., specimens not adhering to the criteria for the other three categories). Additionally, all TMJs were classified as harmonized (such as convex condyle and fossa, or angled condyle and fossa) or discrepant (such as convex condyle and flat fossa, or angled condyle and concave fossa).

Measurements on coronal and axial images

All measurements were performed on a personal computer with a measuring tool called Virtual Place (AZE Co., Tokyo, Japan). The items measured were Angle 1 (angle between the axis of the ramus and transversal condyle diameter on coronal images; Fig. 2) and Angle 2 (angle between the s-axis of the condyle and the direction of the LPM, at the center of the condyle on axial images;

Table 1 Distribution of condyle and fossa shapes of joints, according to mediolateral disk position

	Medial				Normal				Lateral			
	Convex	Angled	Flat	Other	Convex	Angled	Flat	Other	Convex	Angled	Flat	Other
Condyle	7	1	1	0	17	2	7	0	8	1	8	0
Fossa	Convex	Angled	Flat	Other	Convex	Angled	Flat	Other	Convex	Angled	Flat	Other
	7	1	1	0	15	2	9	0	10	1	6	0

Table 2 Morphologic harmonization between the condyle and fossa, according to mediolateral disk position

Disk position	Harmonized	Discrepant	Total
Medial	7	2	9
Normal	19	7	26
Lateral	13	4	17
Total	39	13	52

No significant difference in harmonization status in relation to mediolateral disk position ($P > 0.05$, χ^2 test)

Table 3 Values for Angles 1 and 2, according to mediolateral disk position

Disk position	No. of joints	Angle 1		Angle 2	
		Mean	SD	Mean	SD
Medial	9	88.6	11.7	70.2	8.5
Normal	26	90.9	10.7	66.7	8.1
Lateral	17	90.1	10.5	60.1	9.5
Total	52	90.2	10.6	65.1	9.3

*One-way analysis of variance showed significant differences in relation to disk position for Angle 2. Tukey's post hoc test also showed significant differences in relation to disk position for Angle 2 ($P < 0.05$).

Angle 1: Angle between the axis of the ramus and transversal condyle diameter on coronal images.

Angle 2: Angle between the s-axis of the condyle and the direction of the LPM at the center of the condyle on axial images.

Fig. 3). These measurements were performed twice by two oral radiologists, and the means of the measurements were analyzed.

Statistical analysis

The rates of the various morphologies of the condyle or fossa and of morphologic harmonization among the normal and medial and lateral disk displacement cases were analyzed using the χ^2 test. Each measurement was categorized as medial or lateral disk displacement or normal position and analyzed using one-way analysis of variance (ANOVA). Tukey's test was used as a post-hoc test after ANOVA. All statistical analyses were performed using IBM SPSS Statistics Base 19 (IBM Japan, Tokyo, Japan). A P value of less 0.05 was considered to indicate statistical significance.

Results

The distributions of condyle and fossa shapes are shown in Table 1; other condyle and fossa shapes were not detected. Coronal morphologic harmonization between the condyle and fossa in the sideways disk displacement group and contralateral sides is shown in Table 2; there

were no significant differences.

Angle 1, the angle between the axis of the ramus and the transversal condyle diameter on coronal images, did not significantly differ in relation to mediolateral disk position, but Angle 2, the angle between the s-axis of the condyle and the direction of the LPM at the center of the condyle on the axial image, did significantly differ by disk position. In addition, the post-hoc test showed significant differences in relation to mediolateral disk position. Angle 2 values for the medial, normal, and lateral disk positions were 70.2°, 66.7°, and 60.1°, respectively (Table 3).

Discussion

The present results suggest that the angle of the LPM in relation to the condyle is a risk factor for sideways disk displacement of the TMJ. This variable was investigated because the LPM controls movement of the condyle and disk. Our hypothesis was that functional disharmony caused by the position and direction of TMJ components and muscles induces disk displacement of the TMJ. Some previous evidence suggests a relationship between anterior disk displacement and LPM conditions (9,14).

The LPM is a bicipital muscle, and the inferior head of the LPM was evaluated on axial images in this study, as was the case in a previous study (15). The inferior head of the LPM runs from the infratemporal crest of the sphenoid bone to the pterygoid fossa of the mandible and is involved in jaw opening, protrusion, and contralateral jaw movements (16). In addition, activity of the inferior head of the LPM is closely correlated with the direction of the muscle fibers during horizontal movement (16). Thus, the angle between the inferior head of the LPM and the condyle seems to be an indicator of functional harmonization of the condyle and LPM complex. It is noteworthy that a more-medial disk position correlated with a greater angle between the inferior head of the LPM and condyle in the present study. This suggests that the angle of the inferior head of the LPM to the condyle must be correct during jaw function, to ensure correct mediolateral disk position of the TMJ.

Sideways disk displacement is often observed in patients with internal derangement. Foucart et al. (17) reported that 37% of joints with internal derangement had sideways disk displacement, and pure sideways disk displacement, ie, with no anterior disk displacement, was seen in 4% of joints with internal derangement. Thus, the present study targeted an uncommon pathology of internal derangement of the TMJ. Most patients with sideways disk displacement are strongly affected by the pathology of anterior disk placement, and we believed that evaluation of the anatomic properties of cases of pure sideways disk displacement might clarify the pathogenesis and risk factors of sideways disk displacement in the present study. Almășan et al. (18) investigated whether an index was correlated with anterior and coronal disk displacement, but their sample had no cases of pure sideways disk displacement. To the best of our knowledge, no previous study has limited its investigation to cases of pure sideways disk displacement. This study included evaluation of coronal morphologic harmonization between the condyle and fossa, which was identified as a potential risk factor for anterior disk displacement in our previous study (10). However, there was no relationship with sideways disk displacement, as in the results of our previous study. Therefore, this indicator directly affects anterior disk position of the TMJ, and more complex mechanisms may be involved in sideways anterior disk placement. Almășan et al. (18) found no significant association between condylar angle to the midsagittal line and the anterior disk displacement plane. We also evaluated the condylar axis, which was not the direct angle to the midsagittal line but the relative angle to the axis of the ramus. Although this covariate yielded no

significant findings, it may be related to the pathogenesis of internal derangement of the TMJ, as indicated by the greater standard deviation of the values.

Identification of the risks and predictive factors of diseases is important in preventing and slowing their onset and progression. Abnormal habits, bruxism, malocclusion, psychological problems, and anatomic vulnerabilities are related to TMD pathogenesis (19-21). However, the causes and pathology of TMD are considered multifactorial (19). The present study of risk factors related to anatomic features on MRI had some limitations. First, only a small number of joints were studied. Sideways disk displacement almost always accompanies anterior disk displacement. However, although the study population was extremely limited, data from this population could identify the angle of the LPM relative to the condyle as a risk factor. Second, the LPM evaluated on axial images was the lower head, which does not connect to the disk. Thus, this parameter indirectly affects disk position through mandibular movement. Evaluation that includes the direction of the superior head of the LPM may be adequate, but it is generally believed that axial slice images allow evaluation of the superior head of the LPM. Volume rendering using MRI data enables evaluation of the direction of the superior head of the LPM. Third, evaluation of mediolateral disk position was qualitative. Eberhard et al. (22) reported that quantitative evaluation of mediolateral disk position more accurately described the relationship between mediolateral disk position and other variables, including the angle of the LPM relative to the condyle. Additional studies, with larger numbers of participants, are needed in order to investigate the complex pathologies of anterior and sideways disk displacement of the TMJ.

In conclusion, the present study attempted to identify risk factors for sideways disk displacement of the TMJ. The angle of the LPM relative to the condyle was correlated with mediolateral disk position. The present results suggest that a greater angle of the inferior head of the LPM to the axis of the condyle on axial MRI images may cause medial disk displacement and that a smaller angle may result in lateral disk displacement.

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