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Morphology of the articular eminence in temporomandibular joints and condylar bone change

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SUMMARY **The purpose of the present study was to investigate the relationship between the inclination of the articular eminence and temporomandibular joint (TMJ) pathology in orthognathic surgery patients with signs and symptoms of TMJ disorders. Twenty-one female orthognathic surgery patients with signs and symptoms of TMJ disorders were examined using pre-treatment helical computed tomography scans. The slope of the eminence in the medial, central and lateral sections of the subjects with osteophyte formation was significantly less than in the subjects with no bone change, and the medial section of the subjects with osteophyte formation was also significantly less steep than in the subjects with erosion. The central and lateral sections in the subjects with anterior disc displacement with reduction were significantly steeper than in subjects with anterior disc displacement without reduction. These results suggest that eminence flattening might occur during changes from erosion to osteophyte formation and from anterior disc displacement with reduction to anterior disc displacement without reduction. This appears to represent adaptation of the condyle, articular disc and articular eminence to changes in loading.**

KEYWORDS: **slope of articular eminence, condylar bone change, osteoarthritis, helical computed tomography**

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Introduction

In subjects with temporomandibular joint osteoarthritis (TMJ OA), the relationship of disc displacement (1–6) and condylar bone change (7) to the slope of the eminence have been previously investigated.

Some authors have discovered a positive correlation between a steeper slope of the eminence and an anterior displacement of the disc (1–3). Other studies have found no such correlation (4–6). Furthermore, Ren *et al.* (7) observed a steeper posterior slope in symptom-free volunteers than in patients with internal derangement. The relationship between the above factors therefore remains unclear.

On the contrary, the association of condylar bone change with the inclination of the eminence has recently been reported (7). However, the relationship of the slope of the eminence to the progress of condylar bone change has not yet been investigated.

The aim of this study was therefore to evaluate the inclination of the articular eminence with respect to various stages in the progress of condylar bone change.

Materials and methods

Subjects

In order to elucidate the relationship between condylar bone change, disc displacement and the inclination of the eminence, 27 female subjects with clinical signs and symptoms of TMJ disorders were selected from patients scheduled for orthognathic surgery, with exclusion criteria being the presence of the congenital craniofacial anomalies and/or systemic disease. A subjective

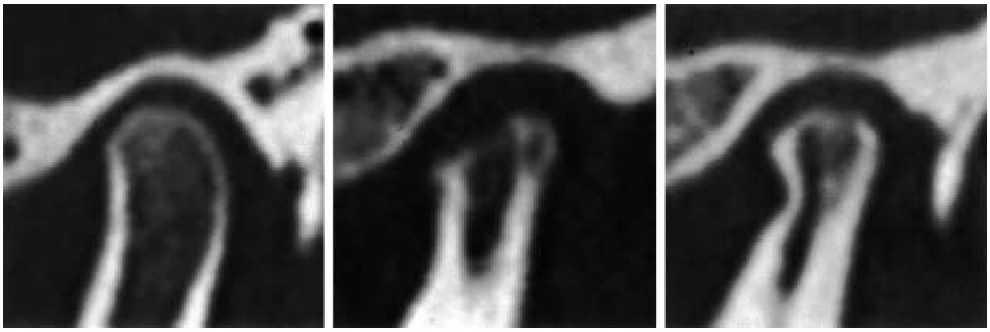

Fig. 1. Classification of condylar bone change. Sagittal reconstruction of axial computed tomography images of the condyle in closed mouth position. (a) A normal condyle, displaying typical morphology. (b) Erosion: a localized area of decreased bone density on the superior area of the cortical condylar surface. (c) Osteophyte formation: a bony protrusion formed on the condylar surface, usually on the anterior part.

questionnaire documented the presence or absence of TMJ pain, TMJ sounds and difficulty of mouth opening. Signs of such TMJ disorders were clinically verified during initial consultation for orthognathic surgery, using techniques previously described (8). Prior to their acceptance for orthognathic surgery and after informed consent was obtained, these patients underwent a helical computed tomography (CT) scan to visualize bone structures and nerves and vessels as well as TMJ internal derangements and condylar bone changes. Six subjects with unilateral condylar bone change were excluded, due to the possibility of uncontrolled influences between their healthy and deformed sides (9).

Ten subjects (mean age 21·44 years, range 17·9–24·6 years) with no condylar bone change (NBC group), and 11 subjects (mean age 22·80 years, range 17·5–24·3 years) with bilateral condylar bone change (BCBC group) were included in the present study. The BCBC group joints were further divided into erosion (10 joints) and osteophyte formation (12 joints) subgroups, according to type of condylar bone change (10) (Fig. 1). Informed consent was obtained from each of them.

Imaging studies

Each subject's TMJs were bilaterally examined with helical CT (Xvigor Real)*. Each patient was placed in a supine position, and CT scans were obtained with the mouth closed and then with the mouth maximally opened. Helical scans were taken parallel to the Frankfort plane, starting at a level a few millimetres above this plane, over a distance of 5 cm at 120 kV, 100 mA and 1 mm collimation, with the scanning table being advanced in increments of 1 mm per rotation.

The scan data was reformatted into 1·0 mm interval axial images and evaluated in soft-tissue display mode. In bone-display mode, the scan data was also reformatted into 0·5 mm-interval axial images at 4× magnification and transferred to a Medical Viewer INTAGE RV version 1·3† workstation. Oblique parasagittal and paracoronal reconstructed images, oriented at right angles to the long axis of the condyle, were obtained and evaluated in this mode.

Condylar bone changes and disc position were diagnosed according to previously-reported definitions using hard and soft tissue images (10, 11) as follows: based on the hard tissue images, condylar bone changes were categorized as erosion or osteophyte formation, and soft tissue images allowed for categorization of the joints as normal disc position (Normal), anterior disc displacement with reduction (ADDW) or anterior disc displacement without reduction (ADDWO) (Fig 2).

The reconstructed CT hard and soft tissue images were independently assessed by two radiologists for condylar morphology and disc displacement. If their evaluations differed, the CT images were rechecked by the two radiologists together, and only those findings on which both radiologists concurred were recorded. No information from the clinical examination was

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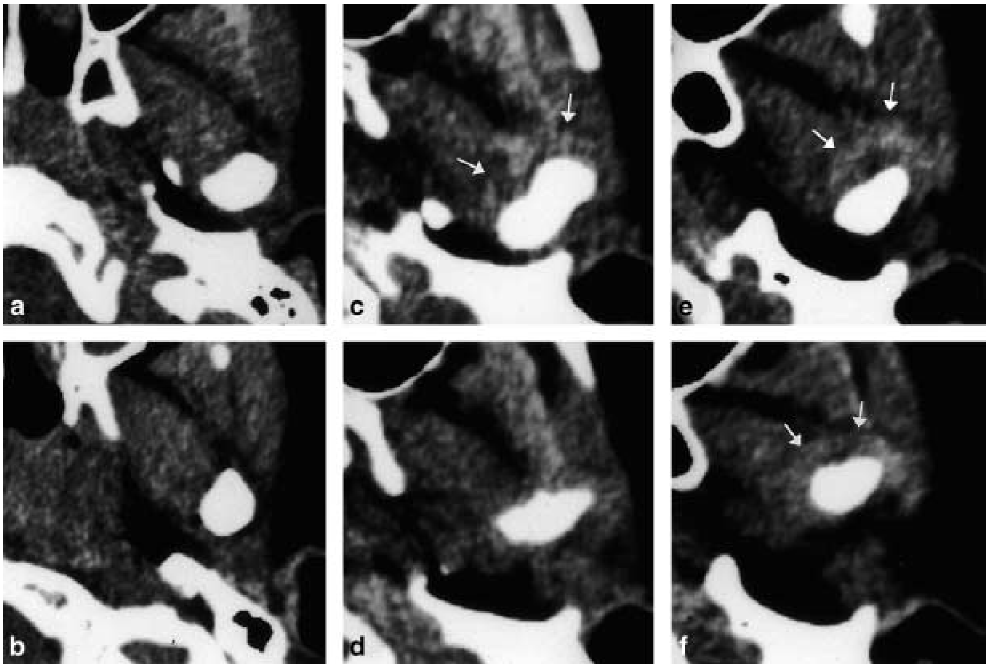

Fig. 2. Classification of articular disc displacement and soft tissue axial helical computed tomography temporomandibular joint images are given. Normal disc position [closed (a) and open (b) mouth position]: no area of high density soft tissue in front of the condyles. Anterior disc displacement with reduction [closed (c) and open (d) mouth position]: no area of high density soft tissue in front of the condyles in open mouth position (d), but an area of high-density soft tissue (arrows), semilunar in shape, in front of the condyle in closed mouth position (c). Anterior disc displacement without reduction [closed (e) and open (f) mouth position]: in both (e) and (f), areas of high-density soft tissue (arrows), semilunar in shape, in front of the condyles.

available to the radiologists at the time the radiographs were interpreted.

Measurement of the slope of the articular eminence

The above reconstructed TMJ hard tissue images were transferred to National Institute of Health software (NIH Image version 1·62‡) for measurement of the slope of the articular eminence. Three sections from each joint, representing the lateral, central and medial parts of the condyle, were measured with this software.

The technique for measuring the posterior-slope angle (PSA) of the eminence is shown in Fig. 3. A reference line, parallel to the Frankfort plane, was first drawn tangential to the roof of the glenoid fossa. A second line parallel to the first was then drawn through the uppermost surface of the condyle *U*, intersecting with the posterior slope of the eminence. This intersection point *E* was used as the reference

‡National Institute of Health, Bethesda, MD, USA.

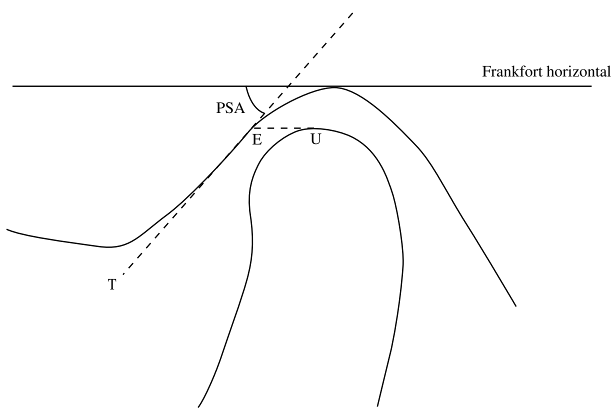

Fig. 3. Measurement of the slope of the eminence on helical computed tomography images; *U*, top of the condyle; *E*, intersection point of the line parallel to the Frankfort horizontal through point *U* and the posterior slope of the articular eminence; *T*, line through point E and tangential to the posterior slope of the articular eminence; PSA, posterior-slope angle of the articular eminence.

point for measuring the PSA of the eminence. Another line T was then drawn through E, tangentially to the posterior slope of the eminence. The PSA formed at the intersection of T and the Frankfort plane was measured, showing the inclination of the posterior slope of the eminence (Fig. 3).

Measurement precision

Thirty-five randomly selected reconstructed images from each section were measured twice over a 1-week interval. The results of these two measurement registrations were compared, and their precision was calculated as

$$s = \sqrt{\sum d^2/2n},$$

where d is difference between the two measurements and n is number of reconstructed CT images sampled twice.

Statistical analysis

The Mann–Whitney U-test was used when comparing any two groups, and an analysis of variance (one-factor ANOVA) was performed when comparing the differences among any three or four groups. The Scheffe test was performed to analyse and differentiate the effect of the osseous changes on the slope of the articular eminence in the one-factor ANOVA. A probability level of <5% ($P < 0{\cdot}05$) was considered to be significant.

Results

Measurement precision

The measurement precision for the slope of the eminence was 1·8° for the lateral, 2·1° for the central and 2·0° for the medial sections of the joint.

Condylar bone change and disc position

Table 1 shows the relationship between condylar bone change and disc position. Of the 20 joints in the NBC 15 showed normal disc position and the remaining five showed ADDW. Of the 10 joints with erosion eight showed ADDWO with the remaining two showing ADDW. All of the 12 joints with osteophyte formation showed ADDWO.

Table 1. Condylar bone change vs. disc position

		BCBC (n = 22 joints)	
	NBC (n = 20 joints)	Erosion (n = 10 joints)	Osteophyte (n = 12 joints)
ADDW	5	2	0
ADDWO	0	8	12
Normal disc position	15	0	0

NBC, no condylar bone change; BCBC, bilateral condylar bone change; ADDW, anterior disc displacement with reduction; ADDWO, anterior disc displacement without reduction.

Effect of condylar bone change on the slope of the eminence

The eminence in the lateral and central sections of the joints was significantly steeper in the NBC group than in those of the BCBC group (Table 2).

Comparing the types of condylar bone change, there were significant differences in the slope of the eminence in all sections of the joints (Table 3). The slope of the eminence in the medial, central and lateral sections of the osteophyte group was significantly less than in the NBC group, and the medial section of the osteophyte group was significantly less steep than that of the erosion group.

Effect of disc position on the slope of the eminence

While there were no significant differences between the normal disc position group and the displaced disc groups taken together (ADDW + ADDWO) (Table 4), the central and lateral sections of the eminence in the ADDW group were significantly steeper than in the ADDWO group (Table 5).

Discussion

Various methods have been used in previous studies to measure the inclination of the posterior slope of the articular eminence. Kerstens *et al.* (1) used panoramic radiography, which only depicts the most lateral part of the articular eminence. The inclination of its posterior slope is difficult to measure by drawing a line tangential to its posterior surface, as this varies in morphology and may be flat, convex or concave. Panmekiate *et al.* (4) and Ren *et al.* (7) used arthrography, which can diagnose both disc displacement and bone condition. Kurita *et al.* (12), Major *et al.*

Table 2. Slope of eminence v. condylar bone change

	NBC (n = 20 joints)		BCBC (n = 22 joints)		Mann–Whitney U-test
	Mean	s.d.	Mean	s.d.	
Medial section of condyle	44·3	9·8	38·8	14·3	NS
Centre section of condyle	50·2	12·1	39·9	13·5	*
Lateral section of condyle	45·9	10·2	36·6	11·0	**

Unit, mm; $^*P < 0{\cdot}05$; $^{**}P < 0{\cdot}01$.
NBC, no condylar bone change; BCBC, bilateral condylar bone change; NS, not significant.

Table 3. Slope of eminence v. type of condylar bone change

	NBC (n = 20 joints)		Erosion (n = 10 joints)		Osteophyte (n = 12 joints)			Scheffe's test		
	Mean	s.d.	Mean	s.d.	Mean	s.d.	ANOVA	Erosion & osteophyte	NBC & osteophyte	NBC & erosion
Medial section of condyle	44·3	9·8	47·2	12·5	32·4	12·5	**	*	*	NS
Centre section of condyle	50·2	12·1	45·9	11·9	34·6	13·6	**	NS	*	NS
Lateral section of condyle	45·9	10·2	41·9	11·1	32·0	9·5	**	NS	*	NS

Unit, mm; $^*P < 0{\cdot}05$; $^{**}P < 0{\cdot}01$.
NBC, no condylar bone change; BCBC, bilateral condylar bone change; NS, not significant.

Table 4. Slope of eminence v. disc displacement

	Normal disc position (n = 15 joints)		Disc displacemnt (ADDW+ADDWO) (n = 27 joints)		Mann-Whitney U-test
	Mean	s.d.	Mean	s.d.	
Medial section of condyle	43·6	11·3	40·8	13·1	NS
Centre section of condyle	47·5	12·6	43·5	14·6	NS
Lateral section of condyle	41·6	7·5	40·9	13·5	NS

Unit, mm; NS, not significant.
ADDW, anterior disc displacement with reduction; ADDWO, anterior disc displacement without reduction.

Table 5. Slope of eminence v. disc position

	Normal disc position (n = 15 joints)		ADDW (n = 7 joints)		ADDWO (n = 20 joints)			Scheffe's test		
	Mean	s.d.	Mean	s.d.	Mean	s.d.	ANOVA	Normal & ADDW	Normal & ADDW	ADDW & ADDWO
Medial section of condyle	43·6	11·3	49·0	8·8	37·7	13·3	NS	NS	NS	NS
Centre section of condyle	47·5	12·6	54·6	9·6	39·4	14·1	*	NS	NS	*
Lateral section of condyle	41·6	7·5	53·1	11·5	36·4	11·5	**	NS	NS	**

Unit, mm; $^*P < 0{\cdot}05$; $^{**}P < 0{\cdot}01$.
ADDW, anterior disc displacement with reduction; ADDWO, anterior disc displacement without reduction; NS, not significant.

(13), Sulun *et al*. (14) and Galante *et al*. (6) used magnetic resonance imaging (MRI), which has the advantage of precisely diagnosing disc position and Major *et al*. (13) and Galante *et al*. (6) used MRI together with tomography, to compensate for the disadvantages in using MRI to diagnose bone structure. Helical CT has the advantages of not only being able to diagnose the three-dimensional details of bone structure, but also disc position (11), and was therefore chosen for use in the present study.

Remodelling, especially osteoarthritic remodelling, has been found to influence the slope of eminence (15). Recently, Ren *et al*. (7) reported that osseous condylar change is more related to the slope of the eminence than to the presence of disc displacement, using precise image diagnosis techniques in establishing his control group. However, the relationship between different kinds of condylar bone change and the slope of the eminence remained to be investigated.

The relationship found in the present study between condylar bone change and slope of the eminence was in agreement with previous studies which reported that the medial, central and lateral sections of the eminence were flatter in joints with osteoarthrotic changes than in joints with normal bone structure (16–18). It may be that flattening of the articular eminence could provide a larger loaded surface area, thereby reducing the force per unit area on the TMJ.

Furthermore, the present study shows that the slope of the medial, central and lateral sections of the osteophyte group were flatter than in the erosion and the NBC group, with little difference in the slope of the eminence between the erosion and NBC groups. The results of the present study therefore seem to show the changes in the slope of the eminence might reflect the details of the progress of TMJ OA, showing that the slope of the eminence decreased with an increase in the severity of the condylar bone change.

Osteoarthritis progresses from NBC, through erosion, to osteophyte formation with a disappearance or reduction of TMJ signs and symptoms (20). The present study suggested that in addition to the morphological changes in the condyle (from erosion to osteophyte), a flattening of the eminence might also be involved as a reaction to loading on the TMJ, and assist in the reduction of symptoms. This idea seems to be supported by the evidence of the effect of surgical resection of the eminence on the range of motion of the condyle (1).

Concerning disc displacement, several studies reported steep eminences in subjects with disc displacement. However, some of them did not use precise image diagnosis techniques to ascertain the relationship between the steep eminences and the subjects' disc displacement (1–3), and in one which used precise imaging techniques (14), the inclination of the slope of the eminence was measured at the inflection point of the eminence. As our criterion of the inclination of eminence was the point on the eminence at the top of the condyle, our measurements can offer a clear picture of the exact relationship between the inclination of eminence and condylar functional movement. These differences in measurement method might be responsible for differences between our results and those of Sulun *et al*. (14).

Studies using precise imaging techniques showed no relationship between the presence of disc displacement and the inclination of the eminence (4, 7). The present study also showed no significant differences between normal disc position and disc displacement with respect to the inclination of the eminence, but a significant difference in this inclination between ADDW and ADDWO, which is in agreement with Panmekiate *et al*. (4). These results might be related to the findings that 71·4% (five of seven) of ADDW were NBC and all of ADDWO showed condylar bone change, with 60·0% (12 of 20) of ADDWO having severe TMJ pathology (osteophyte formation), which might reflect their progress from ADDW to ADDWO over the course of their osteoarthritic changes (4, 7, 12, 18, 19).

The present study suggested that flattening of the eminence seems to occur during changes from erosion to osteophyte, and from ADDW to ADDWO. It seems that the functional unit of the condyle, articular disc and eminence might respond adaptively to loading in the TMJ.

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