Title: Thickness of the roof of the glenoid fossa and condylar bone change: a CT study

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ABSTRACT

Objective: The aim of this study is to investigate the relationship between the thickness of the roof of the glenoid fossa in the temporomandibular joint (TMJ), and the existence and types of condylar bone change.

Material and methods: Helical computed tomography (CT) was used to measure the thickness of the roof of the glenoid fossa at its thinnest part in 37 orthodontic patients with temporomandibular disorders. Condylar bone changes were classified into four types: no bone change (24 joints), flattening (19 joints), osteophyte (13 joints) and erosion (18 joints).

Results: The roof of the glenoid fossa was significantly thicker in joints with bone change than in joints with no bone change (Mann-Whitney U-test, $p<0.05$). There was also a significant difference in relation to the type of condylar bone change: the thickness of the roof of the glenoid fossa in the erosion group was significantly larger than in the no bone change ($p<0.01$), flattening ($p<0.05$) and osteophyte formation ($p<0.05$) groups (Kruskal-Wallis and Games-Howell tests).

Conclusion: The results of the present study suggested that compensative bone formation in the roof of the glenoid fossa might help to withstand the increased stress in the TMJ accompanying condylar bone change (especially erosion).

Keywords: roof of the glenoid fossa; condylar bone change; helical CT

Introduction

Recently it has been shown [1] from autopsy material that the thickness of the roof of the glenoid fossa in the temporomandibular joint (TMJ) seems to be associated with perforation of the disc or posterior attachment, and that progressive remodeling with thickening of the roof of the glenoid fossa seems to be associated with such perforation of the disc or posterior attachment. Retrospective studies support the general idea that an TMJ internal derangement is likely to progress to osteoarthritis.[2,3] Katzberg *et al.*[4] suggested that the obstruction by disc displacement without reduction produced compressive forces that impaired contacting structures in the joint. However, the relationship of the status of condylar bone change and disc condition, to the thickness of the roof of the glenoid fossa has not yet been assessed in previous studies.[1-4]

The purpose of this investigation was therefore to clarify the relationship between the thickness of the roof of the glenoid fossa and condylar bone change, using helical computed tomography (CT).

Materials and methods

In order to elucidate the relationship between condylar bone change, disc displacement and thickness of the roof of the glenoid fossa, forty-one subjects (27 female and 14 male; mean age 22.3 years, range 14-33 years) were selected from orthognathic surgery patients with clinical signs and symptoms of TMJ disorders. A TMJ subjective 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 treatment, using previously-described techniques.[5]

Prior to their acceptance for orthognathic treatment, these patients underwent a helical CT to validate bone structures and directions of nerves and vessels as well as TMJs internal derangements and condylar bone changes after informed consent was obtained. Four subjects with unilateral condylar bone change were excluded from initial 41, due to the possibility of uncontrolled influences between their healthy and deformed sides.[6] The remaining 37 subjects who finally participated in the present study included 12 subjects with no condylar bone change and 25 subjects with bilateral condylar bone changes. The bone change group joints were then further divided into flattening, osteophyte and erosion sub-groups, based on their type of condylar bone change.

The study protocol was approved by the University Institutional Review Board.

All the subjects were scanned with an Xvigor Real (Toshiba Medical, Tokyo, Japan) helical scanner. Each subject was placed in a supine position, and multiple axial slices were obtained from a point superior to the roof of the glenoid fossa to the neck of the condyle in intercuspal position and also in maximally opened position. Helical scans were taken parallel to the Frankfort plane, starting at a level of a few millimeters above this plane, over a distance of 5 cm, at 120 kV, 100 mA, with 1 mm collimation. The scanning table was advanced with increments of 1 mm/rotation.

Condylar bone change and disc displacement were diagnosed according to previously-reported definitions using hard and soft-tissue images [5,7] (**Figures 1 and 2**) as follows: based on these images, condylar bone changes were categorized as flattening, osteophyte formation or erosion, and joints were categorized either as having normal disc position (Normal), disc displacement with reduction (ADDW), or disc displacement without reduction (ADDWO).

The reconstructed CT bone and soft-tissue images were independently assessed twice by two oral and maxillofacial radiologists for condylar morphology and disc displacement.

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

Measurement of the roof of the glenoid fossa

The scan data was reformatted into 0.5 mm-interval axial images at 4 fold magnification using the software included on the Xvigor Real CT, and transferred to a Medical Viewer INTAGE RV version 1.3 (KGT Inc., Tokyo, Japan) workstation. Paracoronal reconstructed images oriented at right angles to the long axis of the condyle were obtained and evaluated in bone display mode (window width 4000; window level 1000). The thinnest area of the glenoid fossa was identified among the multiple slices on the monitor and transferred to the Scion image program (Beta release 4, Scion Corporation, Frederick, MD, USA) for measuring (**Figure 3**). Linear measurements were made three times on the monitor by a single investigator, and their mean value was recorded.

Statistical Analysis

Results were statistically analyzed using the StatView software program (version 5.0.1, SAS Institute Inc., Cary, NC, USA). The Mann-Whitney U-test was used when comparing any two groups, and an analysis with the Kruskal-Wallis test and a post-hoc test (Games-Howell) were performed when comparing the differences among the four groups. A probability level of less than 5% ($p<0.05$) was considered to be significant.

Results

The distribution of the condylar bone change in the subjects was: 12 subjects with no condylar bone change (6 female and 6 male; mean age 21.2 years, range 14-26 years) and

25 subjects with bilateral condylar bone changes (18 female and 7 male; mean age 23.4 years, range 15-33 years).

The distribution of condylar bone change and disc displacement is shown in **Table 1.** Flattening (19/74, 25.7%) was the most common and erosion (18/74, 24.3%) was the second most common feature found in the bone change group. As for the relationship between disc displacement and condylar bone change, all joints in the no bone change group showed normal disc position and in the bone change group, all joints with erosion showed ADDWO. Joints with osteophyte formation showed a high ratio of ADDWO (11/13, 84.6%) but joints with flattening showed more normal disc position (11/19, 57.9%).

The thinnest part of the roof of the glenoid fossa was significantly ($p<0.05$) thicker in the bone change group than the no bone change group (**Table 2**). There was also a significant difference in the thinnest part of the roof of the glenoid fossa in relation to the kind of bone change (**Table 3**). The thickness of the roof of the glenoid fossa in the erosion group was significantly larger than in the no bone change ($p<0.01$), flattening ($p<0.05$) and osteophyte formation ($p<0.05$) groups (Kruskal-Wallis and Games-Howell tests).

Discussion

Since much attention has already been paid to bone changes in the condyle and the articular eminence in TMJ osteoarthritis, we chose to focus on the glenoid fossa in the present study.

As for the thickness of the roof of the glenoid fossa, an autopsy study showed that the minimum thickness of the roof of the glenoid fossa varied between 0.5 and 1.5 mm, with an average of 0.9 mm.[8] Eckerdal and Ahlqvist [9] reported that the minimum thickness was on average 1.1 mm (range 0.1-3.6 mm) in a microradiography study. As for the relationship between disc displacement and the thickness of the roof of the glenoid fossa in TMJ autopsy specimens, the thickness of this roof was on average 0.6 mm in joints with normal disc position, 1.1 mm in joints either with disc displacement or disc displacement with osteoarthritis, and 2.6 mm in joints with osteoarthritis and perforation.[1] However, no evaluation of the condition of condylar bone change was made in the above studies.

In the present study, the average thickness of the roof of the glenoid fossa in joints with no condylar bone change was 0.7 mm, which coincided with a previous study.[1] On the other hand, there were significant differences ($p<0.05$) in the thickness of the roof of the glenoid fossa due to the existence and kinds of condylar bone change, with the erosion sub-group showing the thickest roof.

As for the reaction of the TMJ to mechanical stress, a study of biomechanical simulation in the TMJ [10] showed that morphological changes in the condyle and glenoid fossa altered the stress distribution, suggesting the existence of a mechanism for maintaining or changing condylar morphology in response to the stress distribution in the area. A study using strain gauge measuring techniques showed that during mandibular movements, a buffer effect on the forces is produced not only by the articular disc but also by the bone of the upper wall of the glenoid fossa.[11] Honda *et al.* [1] reported that mechanical stimulation may cause an increase in bone thickness in the glenoid fossa because of an incomplete shock absorption function resulting from a perforation of the disc or retrodiscal connective tissue.

The present study showed that the roof of the glenoid fossa in joints with erosion was the thickest of all sub-groups, with all joints with erosion also showing ADDWO. It has been suggested that erosion tends to appear during a sequence of condylar bone change in response to increasing mechanical stress during the sequence.[12] Erosive changes in the condyle usually also occur in joints with advanced disc displacement,[13] as the articular disc can then no longer act as a kind of shock absorber for the stress in the TMJ. The results of the present study suggested that compensative bone formation in the roof of the glenoid fossa might help to withstand the increased stress in the TMJ accompanying condylar bone change, especially erosion.

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Figure legends

Fig. 1 Condylar morphology classification

Sagittal view of the condyle in intercuspal position

a. No bone change: a smooth and clear cortical bone surface b. Flattening: a flat bone contour, deviating from the convex form c. Erosion: a localized area of decreased density of the condylar surface and adjacent subcortical bone d. Osteophyte: a marginal bone outgrowth on the anterior and/or superior surfaces of the condyle

Fig. 2 Soft tissue axial helical CT TMJ images

a and b: Anterior disc displacement with reduction (ADDW) was defined when the TMJ in closed mouth position (a) shows an area of high-density soft tissue (arrowheads), semilunar in shape, in front of the condyle and the TMJ in open mouth position (b) does not show any such area of high-density soft tissue.

c and d: Anterior disc displacement without reduction (ADDWO) was defined when the TMJ in both closed (c) and open (d) mouth positions show areas of high-density soft tissue (arrowheads), semilunar in shape, in front of the condyles.

Fig. 3 Measurement procedure of the thinnest part of the roof of the glenoid fossa

Paracoronal reconstructed images of the thinnest part of the roof of the glenoid fossa (arrowheads)