The Relationship Between Morphological Changes of the Condyle and Condylar Position in the Glenoid Fossa

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Aims: *To investigate whether condylar morphological changes influence the condyle position in the glenoid fossa as well as the amount of condylar movement from the intercuspal position (IP) to the reference position (RP).* ***Methods:*** *Helical computed tomography was used for precise measurement of the joint spaces at IP and RP in 22 subjects (mean age 22.7 years). Subjects were divided into 2 groups, those without condylar bone changes (n =11) and those with condylar bone changes (n = 11). The latter group was further subdivided into a flattening subgroup and an osteophyte subgroup, according to the type of condylar bone change.* ***Results:*** *There were no significant differences in the width of the anterosuperior or posterosuperior joint spaces at IP between either the 2 groups or the 2 subgroups. On the other hand, during condylar movement from IP to RP, the condyles moved significantly more superiorly and posterosuperiorly in the bone-change group than in the no-bone-change group. There was also greater absolute horizontal condylar movement between IP and RP in the bone-change group. In addition, within the bone-change group, the type of condylar bone change influenced the amount of condylar movement. Joints with osteophyte formation showed the most superior, posterosuperior, and absolute horizontal movement from IP to RP.* ***Conclusion:*** *The findings that condyles of the bone-change group, especially those with osteophyte formation, were located significantly more anteroinferiorly in the glenoid fossa at IP than RP than the condyles of the no-bone-change group suggest that condylar IP-RP positional changes might be related to condylar shape alteration.* J OROFAC PAIN 2004;18:148–155

Key words: condylar bone change, helical computed tomography, osteophyte formation

Several studies have reported a longer retruded contact position–intercuspal position slide (RCP-IP slide) in patients with radiographic signs of osteoarthritis (OA) than in control subjects,[1–3] thereby suggesting that osseous remodeling or condylar lysis may be accompanied by an increased slide. Pullinger et al[4] also found larger slides in temporomandibular joints (TMJs) with degenerative changes than in normal TMJs, and McNamara et al[5] suggested that these slides may in fact be a result of, rather than a cause of, these joint changes.

On the other hand, since orthodontic treatment can change the mandibular occlusal position, it may be important to determine where the final condylar position should be after orthodontic treatment in subjects with OA, because of the potential for a discrepancy between the IP and the RCP. Slavicek defines the reference position (RP) as a physiologic position of the mandible used as the

Fig 1 Sagittal view of the condyle at intercuspal position. *(left)* No bone change—a smooth and clear cortical bone surface. *(center)* Flattening—a flat bone contour, deviating from the convex form. *(right)* Osteophyte—a marginal bone outgrowth on the anterior or superior surface of the condyle.

diagnostic reference position of the TMJ.[6] In RP, the mandible is in a physiologic retral border position. All structures of the joint are unloaded, ie, the ligaments are not in tension in any direction. There is minimal muscle activity and no pressure on cartilaginous structures.[7] Although the articular disc is displaced in joints with internal derangement, this deranged RP has also been considered by some authors to be an unstrained retral border position.[7]

To assess condylar position in the glenoid fossa, transcranial radiography[8,9] and tomography[10–15] have been used. However, the recent introduction of helical computed tomography (CT) has significantly improved upon previous scanning techniques by reducing examination time and radiation doses as well as by providing information on both the bone and soft tissue components.[16,17] Bone structures are better visualized by multiplanar reconstruction (MPR) based on helical CT data,[18,19] and image reformatting of CT scans can also be used to quantify 3-dimensional condylar movements.[20–22]

The aim of the present study was to use helical CT to investigate whether condylar morphological changes influence the condylar position in the fossa as well as the amount of condylar movement from IP to RP.

Materials and Methods

Subjects

Twenty-six subjects were randomly selected from orthodontic patients who were referred to and accepted by our orthodontic department for treatment of malocclusion. On clinical examination, some subjects had TMJ sounds (eg, clicking), but none had capsular pain, masticatory muscle tenderness, or a limited range of mandibular motion. Exclusion criteria were the presence of systemic inflammatory arthritis, congenital deformity, or unilateral condylar bone change (as opposed to bilateral). Subjects with unilateral condylar bone change were also excluded because of the risk that the affected and unaffected TMJs would influence each other and confound the results of our investigation.[23] The 26 subjects underwent a helical CT to diagnose condylar bone changes. Four patients with unilateral condylar bone change were excluded. The remaining 22 subjects were divided into 2 groups: 11 subjects with bilateral condylar bone changes (5 men and 6 women, mean age 23.8 years, range 21 to 30 years) were placed in the "bone-change" group, and 11 subjects with no condylar bone changes (4 men and 7 women, mean age 21.6 years, range 14 to 35 years) were placed in the "no-bone-change" group. The bone-change group was further divided into a flattening subgroup and an osteophyte subgroup, according to the type of condylar bone change (Fig 1). The study was approved by the Niigata University Institutional Review Board. The subjects were informed of these procedures and gave their consent to be included in this study.

Bite Registration Procedure

Each subject was seated in a dental chair with the backrest reclined 45 degrees. An IP bite registration was performed with the use of vinyl polysiloxane bite registration cream (Exabite II; CG Corporation). The RP bite registration was carried out according to Slavicek's[24] unforced chin-point guidance technique, using pattern resin (CG Corporation) for the anterior portion and Exabite II for the posterior portion.

CT Procedure

Subjects were placed in the CT apparatus in a supine position; the head was stabilized with a cloth band. While the CT scans were being performed, the subject bit into the corresponding bite registration (IP or RP). Subjects were instructed to keep the mandible still in each position during scanning. These helical scans (Xvigor Real;

Toshiba Medical; 120 kV, 100 mA, with 1 mm collimation) were taken parallel to the Frankfort plane, starting a few mm above the glenoid fossa, over a distance of 5 cm. The scanning table was advanced in increments of 1 mm/rotation. In order to ensure similar CT scans in both IP and RP, the Frankfort plane and midsagittal plane were oriented vertically using the light beam of the CT scanner. This procedure was done as quickly as possible in order to reduce the radiation dose to the eyes.

1. Diagnostic Classification for Condylar Bone Change. Condylar bone changes were evaluated according to previously reported definitions[17,18] using reconstructed coronal and sagittal CT images at 0.5 mm slice width. Condylar osseous abnormalities detected by conventional tomography are usually classified as cysts, erosion, osteophytes, sclerosis, concavities, or flattening.[25] We did not detect sclerosis, concavities, or cysts in the study sample. For this reason, only 3 different types of condylar morphology were defined: no bone change, flattening, and osteophyte (Fig 1). Absence of bone change was diagnosed when the condyles had a smooth, clear cortical bone surface. Flattening was diagnosed when the bone contour was flattened, ie, it deviated from the convex rounded form. An osteophyte was defined as a marginal bone outgrowth on the anterior or superior surface of the condyle.

All reconstructed CT bone images were independently assessed by 2 trained radiologists experienced in TMJ imaging with helical CT. A condylar bony change was diagnosed if all or almost all the sections of any given condyle showed the same kind of condylar bone change. If the evaluations of the radiologists differed, the CT images were rechecked by the 2 radiologists together, and only those findings on which both radiologists concurred were recorded. The radiologists were unaware of the findings of the clinical examination.

2. Joint Space Measurements. The scan data were reformatted into 0.5-mm-interval axial images at 4× magnification and transferred to a Medical Viewer INTAGE 2.14 workstation (Kubota Graphics Technologies). All images were evaluated in bone display mode (window width, 4000 HU; window level, 1000 HU). Measurements were made on 2-dimensionally reformatted images with Scion Image software (Scion; version 4.0).

The condyle–glenoid fossa relationship was assessed at IP and RP. From transaxial volume data of the CT scan, 2-dimensional reformatted images in the axial, coronal, and sagittal planes (ie, MPR images) were used to measure joint spaces. The temporal bone around the glenoid fossa was used to establish constant RPs for measuring the width of the joint spaces.

The following reference lines and points were used:

Sagittal Section (through the Highest Contour of the Glenoid Fossa).

- Line A: The line parallel to the upper border of the film, ie, parallel to the Frankfort plane, through the lowest point of the articular eminence (Fig 2a)
- Line B: The line perpendicular to line A, through the highest point of the glenoid fossa (Fig 2a)
- Midpoint of the glenoid fossa (M): the intersection between line A and line B (Fig 2a)

Axial Section (Through the Lowest Point of the Articular Eminence).

- Line C: The line formed by the intersection of the coronal plane through the highest point of the glenoid fossa with the axial plane through the lowest point of the articular eminence (Fig 2b)
- Line D: The line formed by the intersection of the sagittal plane through the highest point of the glenoid fossa and the axial plane through the lowest point of the articular eminence (Fig 2b)

Linear Measurements.
The following 4 linear measurements were used for this study (Figs 2a and 2b):

- Anterosuperior joint space (S1): The distance on a line through point M at 45 degrees from line A between the cortical surface of the condyle and the posterior slope of the articular eminence
- Superior joint space (S2): The distance on line B between the cortical surface of the condyle and the border of the glenoid fossa
- Posterosuperior joint space (S3): The distance on a line through point M at 135 degrees from line A between the cortical surface of the condyle and the temporal bone
- Horizontal joint space (A1): The distance on line C between the cortical surface of the condyle and the entoglenoid wall of the temporal bone

To investigate the amount of IP-RP condylar movement, the differences in anteroposterior, superior, horizontal, and absolute horizontal positions of the condyle in IP and RP were compared. The absolute value of horizontal medio-lateral movement was also calculated.

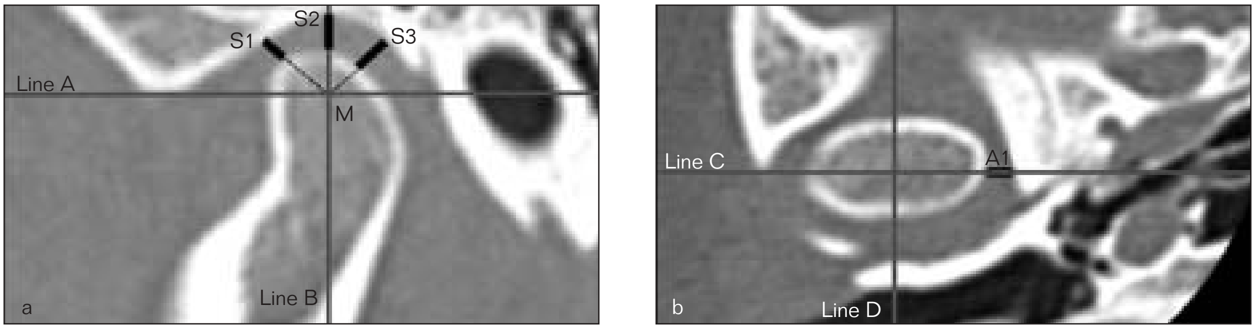

Fig 2 Two reference lines were used in the sagittal section *(a)*. Line A runs parallel to the Frankfort plane through the lowest point of the articular eminence. Line B is perpendicular to line A; it runs through the highest point of the glenoid fossa. The midpoint of the glenoid fossa (M), ie, the intersection between line A and line B, was also used as a reference point. The anterosuperior (S1), superior (S2) and posterosuperior (S3) joint spaces were measured. Two reference lines were also used in the axial section *(b)*. Line C was formed by the intersection of the coronal plane through the highest point of the glenoid fossa with the axial plane through the lowest point of the articular eminence. Line D was formed by the intersection of the sagittal plane through the highest point of the glenoid fossa and the axial plane through the lowest point of the articular eminence. The horizontal joint space (A1) was measured.

3. Measurement Precision. The joint spaces S1, S2, S3, and A1 (Figs 2a and 2b) were identified and accurately plotted on the sagittal, axial, and coronal images. Because the images were projected on the monitor simultaneously, it was possible to locate the endpoints of these spaces easily and accurately. The reproducibility of the condylar joint space measurements was assessed by measuring each selected image twice, with a 1-week interval between measurements. All reference lines and points were redrawn for the second measurement as well. The results of these dual registrations were compared and the measurement precision was calculated as $s = \sqrt{\Sigma d^2/2n}$, where d was the difference between the 2 measurements and n was the number of original images.[13,14] The mean error was 3% and the maximum difference between any 2 measurements was 11%. The coefficient of variation of the condylar joint space measurements (CV = [SD/n] × 100) was calculated to be, on average, 99.1%.

Statistical Analysis

Results were statistically analyzed with the StatView software program (SAS Institute). In the analysis of the joint space data, the Student *t* test was used for the comparison of any 2 groups or subgroups, and a 1-way analysis of variance (ANOVA) was performed with a post-hoc test (Scheffé) for comparison of the differences among any 3 or 4 groups or subgroups. The data for the amount of condylar movement from IP to RP were not normally distributed. The Mann-Whitney *U* test was therefore used to compare any 2 groups or subgroups, and the Kruskal-Wallis test and a post-hoc test (Games-Howell) were used to compare the differences between any 3 subgroups. A probability level of less than 5% ($P < .05$) was considered to be significant.

Results

Joint Space at IP

There were no significant differences in the width of the anterosuperior or posterosuperior joint spaces, either between the bone-change group and the no-bone-change group or between the 2 bone-change subgroups ($P \geq .05$) (Tables 1 and 2).

Condylar Movements from IP to RP

The bone-change group showed significantly larger superior, posterosuperior, and absolute horizontal movements than the no-bone-change group ($P < .05$) (Table 3). There was also a significant difference in the amount of condylar movement between the flattening and osteophyte subgroups ($P < .05$) (Tables 4a and 4b). Condyles with osteophytes showed significantly larger superior, posterosuperior, and absolute horizontal movements from IP to RP than those of the no-bone-change group, and significantly larger superior and posterosuperior movements from IP to RP than those of the flattening subgroup ($P < .05$).

Table 1 Comparison of Joint Spaces (mm) Between No-Bone-Change Group and Bone-Change Group at Intercuspal Position

	Joints with no bone change (n = 22)		Joints with bone change (n = 22)		
Joint space	Mean	SD	Mean	SD	*P*
Anterosuperior	1.63	0.83	1.97	1.02	NS
Posterosuperior	1.84	0.68	2.19	0.70	NS

The Student *t* test was used to determine significance. NS = not significant.

Table 2 Comparison of Joint Spaces (mm) Between Groups According to the Presence and/or Type of Bone Change at IP—No-Bone-Change Group, Flattening Subgroup, and Osteophyte Subgroup

	Joints with no bone change (n = 22)		Joints with flattening (n = 13)		Joints with osteophytes (n = 9)		
Joint space	Mean	SD	Mean	SD	Mean	SD	*P*
Anterosuperior	1.63	0.83	2.17	1.05	1.69	0.95	NS
Posterosuperior	1.84	0.68	2.04	0.61	2.41	0.80	NS

One-way ANOVA was used to determine significance. NS = not significant.

Table 3 Condylar Movements from IP to RP (mm) in the No-Bone-Change and Bone-Change Groups

	Joints with no bone change (n = 22)		Joints with bone change (n = 22)		
Condylar movement	Mean	SD	Mean	SD	*P*
Anterosuperior	0.05	0.33	–0.02	0.56	NS
Superior	–0.14	0.39	0.19	0.46	< .05
Posterosuperior	–0.11	0.42	0.43	0.72	< .01
Horizontal	0.16	0.41	0.07	0.99	NS
Absolute horizontal	0.26	0.36	0.78	0.59	< .001

The Mann-Whitney *U* test was used to determine significance. NS = not significant.

Discussion

Reliability of CT Measurement

Christiansen et al[26] embedded a dried and previously measured human mandible in plastic and scanned it in vitro. They also scanned frozen cadaver heads and measured them in situ. They concluded that linear measurement by conventional CT is accurate, with an observer error within acceptable limits (0.4 to 0.8 mm) when performed in vitro or in situ on TMJs free of significant structural changes. Tyndall et al[27] showed in dried skulls that 2-dimensionally reformatted images are able to detect condylar positional changes within 0.5 mm. Quantitative data analysis improves by decreasing the pixel size. In this study, the pixel size of the reformatted helical CT images was 0.12 mm, a smaller value than that reported by Tyndall et al. Further studies have also shown that 2-dimensional reconstruction from spiral (helical) CT allows for highly accurate linear measurements.[28–30]

Measurement Procedure

In this study, a new method of measuring the joint space width was developed. In order to assess condylar positional changes from IP to RP, the temporal bone around the glenoid fossa (not the condyle itself as in previous joint-space studies[31–34]) was used as a reference for measurement of the changes in the joint space width. The joint spaces in

Table 4a Condylar Movements from IP to RP (mm) in the No-Bone-Change Group and Flattening and Osteophyte Subgroups

Condylar movement	Joints with no bone change (n = 22)		Joints with flattening (n = 13)		Joints with osteophytes (n = 9)		
	Mean	SD	Mean	SD	Mean	SD	*P*
Anterosuperior	0.05	0.33	0.04	0.39	–0.11	0.76	NS
Superior	–0.14	0.39	–0.01	0.35	0.46	0.47	< .01
Posterosuperior	–0.11	0.42	0.09	0.57	0.92	0.65	< .0001
Horizontal	0.16	0.41	0.28	0.68	–0.24	1.31	NS
Absolute horizontal	0.26	0.36	0.60	0.41	1.05	0.72	< .001

The Kruskal-Wallis test was used to determine significance. NS = not significant.

Table 4b Significance of Intergroup Comparison of Condylar Movements from IP to RP

Condylar movement	No bone change + flattening	No bone change + osteophyte	Flattening + osteophyte
Anterosuperior	NS	NS	NS
Superior	NS	< .05	< .05
Posterosuperior	NS	< .01	< .05
Horizontal	NS	NS	NS
Absolute horizontal	NS	< .05	NS

The Games-Howell test was used to determine significance. NS = not significant.

the sagittal and axial planes were measured through the highest point of the glenoid fossa and the lowest point of the articular eminence, respectively. Other researchers have used only the smallest joint spaces for their measurements,[23,32] but this was considered insufficient for the purposes of the present study, as we wanted to obtain a complete picture of the real movement of the condyle in the glenoid fossa from IP to RP.

Condylar Position at IP

There were no significant differences in the width of the anterosuperior and posterosuperior joint spaces between the bone-change and no-bone-change groups. This suggests that the condylar positions in both groups were, on average, concentric, which is in agreement with the results of Ronquillo et al[35] and Katzberg et al.[36] Nevertheless, the joint-space values varied widely between these 2 groups, as can be seen from the large standard deviations in Table 1. One reason for this may be that the shape of hard tissues does not necessarily correspond to the shape of soft tissues, especially in the anterior part of the condyle.[37] Further research is necessary to clarify the differences in condylar position between joints with bone changes and normal joints, taking into account the shape of the soft tissues (including cartilage layers).

IP to RP Condylar Movement

The amount of condylar movement from IP to RP was significantly larger in the group with condylar bone changes than in the group without such changes. Furthermore, in the bone-change group, the osteophyte subgroup showed larger superior, posterosuperior, and absolute horizontal positional changes than the flattening subgroup. This seems to support previous reports showing longer occlusal slides in patients with OA than in controls.[2,3] It has also been reported that the terminal condylar point was more unstable during tapping in joints with disc displacement without reduction and in joints with condylar bone changes than in healthy joints.[38] The larger condylar movement from IP to RP in the osteophyte subgroup may reflect an unstable terminal condylar position. Therefore, pathological bone remodeling and its associated soft tissue alterations might explain the larger IP-RP movements in the osteophyte subgroup.

Making the centric relation (CR) and the IP coincident has been considered by some to be the goal of orthodontic treatment,[39,40] and most dentists who look carefully at the joint-to-dentition relationship agree that a large pretreatment discrepancy between CR and IP makes it more difficult to achieve this posttreatment result.[41–43]

Gaither et al[44] reported that CR-IP discrepancies actually tend to increase with orthodontic treatment and that the discrepancies remain during the retention phase. McNamara et al[5] suggested that the removal of a large discrepancy between retruded contact position and IP may not be advisable because an occlusal RCP-IP slide has not been shown to be a contributing factor to the etiology of temporomandibular disorders. Such a slide may be a consequence of an articular disorder (eg, primary arthrosis) rather than a result of occlusal factors.[5] The present study also showed that in IP, condyles with bone changes are more anterior and inferior to RP than normal condyles. They also have greater IP-RP movement than normal condyles.

In conclusion, these results suggest that the amount of slide depends on, ie, is secondary to, bone remodeling, and that a difference in condylar position between RP and IP might be the consequence of condylar bone change.

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