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Influence of Condylar Guide Inclination on Condylar Positioning during Clenching

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Abstract - *The relationship between the steepness of the articular eminence and the condylar positioning during clenching was investigated in 19 volunteers with natural dentitions. The condylar positioning during maximal voluntary contraction was measured using a mandibular movement analysis system with six degrees of freedom. The sagittal condylar guide inclination was also measured using the same apparatus. A significant negative correlation was observed between the sagittal condylar guide inclination and the distance of ipsilateral condylar positioning. This result suggests that the steepness of the articular eminence is an important factor in condylar positioning during clenching.*

KEY WORDS: Condylar guide inclination, Condylar positioning, Maximal voluntary contraction, Mandibular movement analysis system with six degrees of freedom

INTRODUCTION

Many studies have reported the relationship between facial morphology and stomatognathic functions such as mandibular movements[1-5] and masticatory muscle activity[6,7]. Ingervall[1] first reported the influence of facial morphology on the range of mandibular movement. He stated that the mouth opening capacity correlates with the length of the cranial base and the mandible, the sagittal jaw relation, and the inclination of the mandibular ramus to the mandibular base. Ingervall et al.[6] also described a clear correlation between muscle activity and facial morphology during chewing and maximal bite.

The steepness of the articular eminence is one of the important morphological factors that determine mandibular movement[8]. The degree of convexity of the articular eminence is highly variable but important, since the steepness of this surface dictates the path of the condyle when the mandible is positioned anteriorly[9]. The steepness of the articular eminence has been studied in relation to facial morphology[10,11], posterior loss of teeth[12,13], and temporomandibular joint (TMJ) disk displacement[8,14-21].

In a previous study[22], we investigated the mandibular positioning during maximal voluntary contraction related to simulated loss of posterior occlusal supports in 24 volunteers with natural dentitions. A greater bilateral loss of posterior occlusal support was associated with increased distances of positioning of both condyles. Moreover, subjects could be divided into two groups depending on the condylar mobility following reduced occlusal support. In the first group, by cutting the splint sequentially from the posterior toward the anterior side, the distance of condylar positioning increased and a significant difference was observed among the distances measured under various experimental occlusal conditions. On the other hand, in the second group, no significant difference was observed between the distances measured under all the experimental occlusal conditions. The reason why the subjects can be divided into two groups may depend upon the morphological difference of the TMJ as a fulcrum of mandibular positioning.

The present study analyzed the relationship between the steepness of the articular eminence and the condylar positioning during clenching, employing a mandibular movement analysis system with six degrees of freedom. We tested the hypothesis that the steepness of the articular eminence is an important factor affecting condylar positioning during clenching.

MATERIALS AND METHOD

Subject selection

Nineteen clinical residents (15 males and 4 females) of Matsumoto Dental University were selected as subjects. Their ages ranged from 24 to 31 years (mean age: 25.7). The exclusion criteria were as follows: (i) persons undergoing orthodontic treatment, (ii) persons with missing teeth, (iii) persons with subjective symptoms of temporomandibular disorders, (iv) persons with symptoms of periodontal disease. The study protocol was approved by the Ethics Committee of Matsumoto Dental University (#0020) and informed consent was obtained from all the subjects.

Measurement of the mandibular positioning

Mandibular positioning during maximal voluntary contraction was measured using a mandibular movement analysis system with six degrees of freedom† (Fig. 1). This system consists of a transmitter, two micro electromagnetic sensors, a system electronics unit and a personal computer. A

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pair of resin clutches was attached to the labial surfaces of upper and lower incisors to position the sensors. A rapid cure adhesive agent[‡] was used to fix the clutches.

An original software package was developed to analyze mandibular positioning[23]. The condyles on both sides were selected as two reference points (right condyle: point RC, left condyle: point LC) for subsequent analyses. In this study, the kinematic axis[24] was used to represent the condylar point. The distance and the direction of condylar positioning during three seconds of maximal voluntary contraction in the maximal intercuspal position (MIP) were measured at points RC and LC (Fig. 2). The measurements were repeated five times with rest intervals (1 minute) long enough to relieve the subject's fatigue. For the analysis of the direction of positioning, the occlusal plane was used as the reference plane. Zero degree, +90 degrees and +180 degrees correspond to the posterior, superior and anterior directions, respectively.

To ensure the clenching force at maximum level, electromyography (EMG) was recorded simultaneously from both masseters and anterior temporal muscles using surface electrodes. The raw EMG signals were rectified and displayed on the screen as visual feedback that enabled the subjects to exert maximal voluntary contraction at all measurements.

Measurement of the condylar guide inclination

The condylar guide inclination was investigated by tracking the sagittal condylar path during mandibular protrusive excursion. The subject was instructed to move the mandible from the MIP to the edge-to-edge position and the condylar path between these two positions was measured using the mandibular movement analysis system. The angle between the condylar path and a reference line drawn parallel to the occlusal plane was defined as the sagittal condylar guide inclination.

Statistical analysis

Correlation between the condylar guide inclination and the ipsilateral condylar positioning during clenching was analyzed using Spearman's correlation coefficient by rank test. The level of significance was set at $p<0.05$.

RESULTS

Condylar positioning during clenching

The distances of positioning of points RC and LC during maximal voluntary contraction ranged from 0.2 to 1.0 mm and from 0.2 to 0.9 mm, respectively (Fig. 3). The directions of positioning of points RC and LC ranged from 71 to 121 degrees and from 73 to 125 degrees, respectively (Fig. 4).

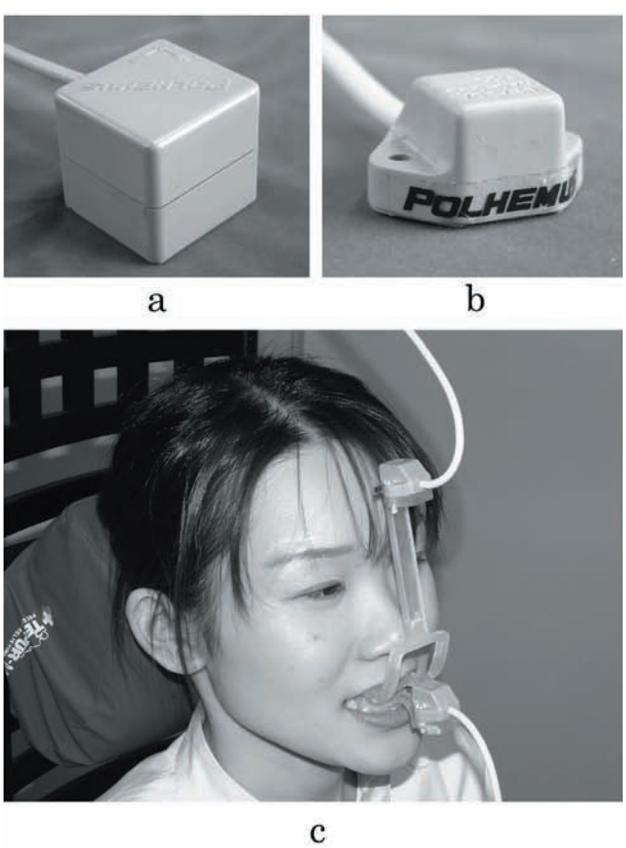

Figure 1. *Mandibular movement analysis system with six-degrees of freedom. a: Transmitter, b: Sensor, c: Upper and lower sensors fixed on the labial surface of subject's incisors.*

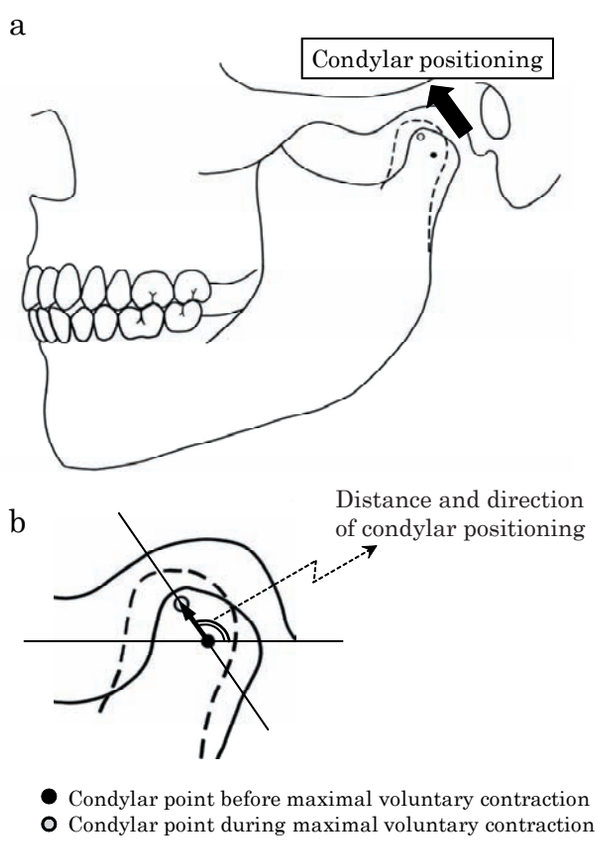

Figure 2. *a: Diagram showing condylar positioning during maximal voluntary contraction. b: Diagram showing distance and direction of condylar positioning during maximal voluntary contraction.*

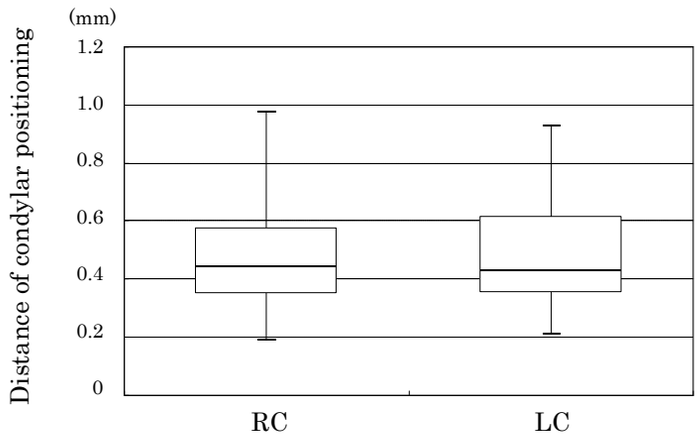

Figure 3. *The distances of positioning of points RC and LC during maximal voluntary contraction*

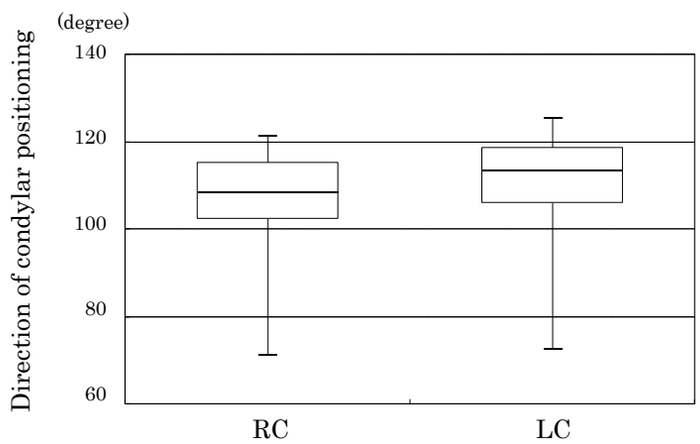

Figure 4. *The directions of positioning of points RC and LC during maximal voluntary contraction*

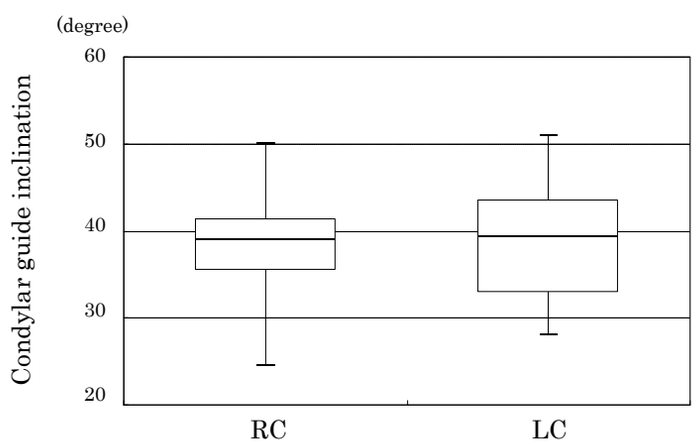

Figure 5. *The sagittal condylar guide inclinations of points RC and LC*

Condylar guide inclination

The sagittal condylar guide inclinations of points RC and LC ranged from 25 to 50 degrees and from 28 to 51 degrees, respectively (Fig. 5).

Relationship between the condylar guide inclination and the condylar positioning

A significant negative correlation was observed between the sagittal condylar guide inclination and the distance of ipsilateral condylar positioning (right side: Spearman's rank correlation coefficient (rs) = –0.51, $p < 0.05$; left side: Spearman's rank correlation coefficient (rs) = –0.55, $p < 0.05$) (Fig. 6). Hence, a steeper condylar guidance was associated with a shorter distance of condylar positioning.

On the other hand, no significant relationship was observed between the sagittal condylar guide inclination and the direction of ipsilateral condylar positioning (right side: rs = 0.05, $p = 0.43$; left side: rs = 0.26, $p = 0.32$).

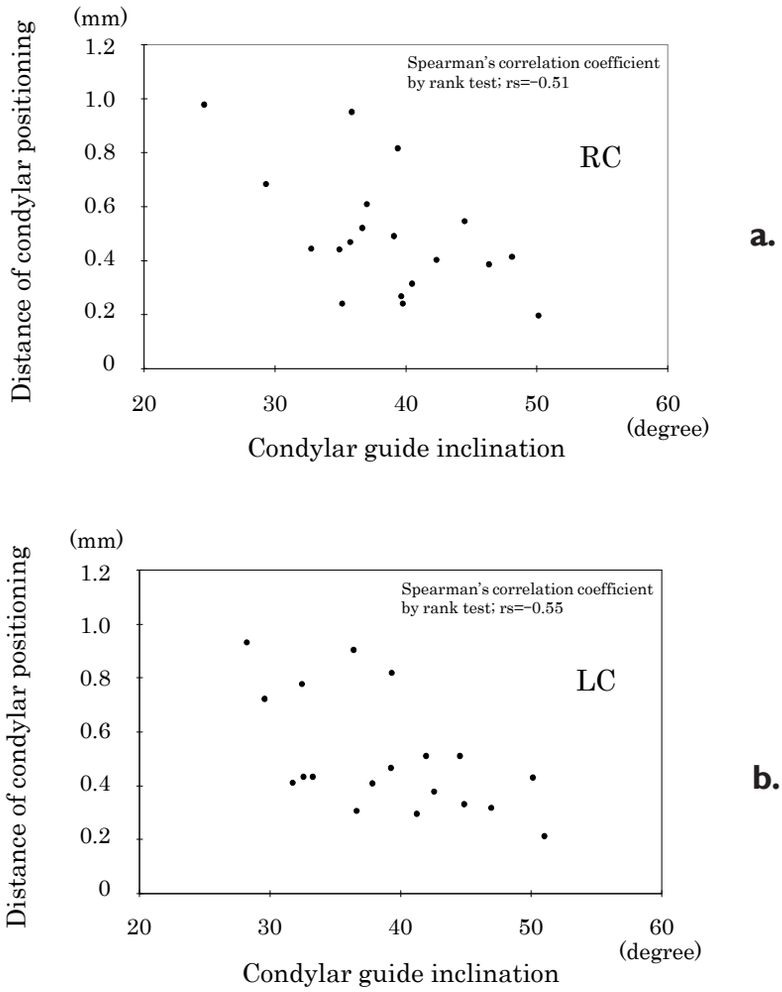

Figure 6a and 6b. *Correlation between condylar guide inclination and ipsilateral condylar positioning. a: RC, b: LC.*

DISCUSSION

In the present study, an original mandibular movement analysis system with six degrees of freedom based on low frequency magnetic transducing technology was used to measure the mandibular positioning. Our previous study showed that when the distance between the transmitter and the sensor was set within 300 mm, the total measurement error was less than 100 μm in distance and less than 0.2 degree in angle[23]. Nevertheless, this system is based on the assumption of mandibular rigidity, and does not take into account physiological deformation under maximal voluntary contraction. Comparing with other jaw tracking systems on the market, the advantages of this system are as follows: first, this apparatus causes minimum discomfort to the subject during measurement because the sensor is small and light-weight (16.3 g), secondly, the mandibular movement can be displayed on a screen after completing the measurement and thirdly, the kinematic axis can be searched automatically using custom designed software.

The mean distances of positioning of points RC and LC during maximal voluntary contraction were 0.46 and 0.45 mm, respectively. These data are comparable with other reports[25-28]. During maximal voluntary contraction, condylar positioning is produced not only by distortion of the periodontal ligament and the periodontium including the alveolar bone[29,30], but also by the lever effect[31,32]. Regarding the lever effect during clenching, Yamazaki et al.[27] reported that the posterior region of the mandible receives a more compressive load than the anterior region because of its proximity to the masseter and the medial pterygoid muscles. This observation agrees with the findings in our preliminary study showing that the distances of positioning at the first molars were greater (but not significant) than that of the central lower incisor. However, since it will be too complicated to identify the role of each anatomical factor, condylar positioning should be studied as a collective mechanism of complex factors instead of separate actions of individual factors.

The condylar guide inclination varies with different protruded positions. In the present study, the edge to edge position was defined as a representative protruded position according to Kohno[24], who stated that the condylar path follows approximately a straight line so far as the mandible moved from the MIP to the edge to edge position. The condylar guide inclination measured in the present study coincided with the range in previous reports[24,33], except for a slight difference depending on the use of different protruded positions or reference planes.

In the present study, a significant negative correlation was observed between the sagittal condylar guide inclination and the distance of condylar positioning during clenching. In other words, steeper condylar guidance is associated with a shorter distance of condylar positioning. This can be explained by the biomechanical difference derived from morphologic features of the condyle, disk and fossa. In the joint with steep inclination, the condyle is fitted rigidly to the shape of the eminence in the stabilized condylar position. Basically, the condylar guide inclination measured in the present study is not synonymous with the steepness of the articular eminence. Isberg et al.[8] showed that the condylar guide inclination is significantly smaller than the steepness of the eminence. The difference in mean values between these two angles was 7.6 degrees. They explained that the condyle follows a path that is less inclined than the eminence to maintain proper condyle disk eminence relationship. However, the difference of these two values may not have a great influence on the results of the present study, and may be negligible if the condylar guide inclination is constantly smaller than the steepness of the eminence.

It is frequently speculated that a steep slope of the eminence predisposes to certain disorders in the condyle/disk relationship. Several authors reported a positive correlation between a steeper slope and the anterior displacement of the TMJ disk[14,15,18]. The inclination of the condylar path during mandibular movement was reported to be increased in patients with TMJ disk displacement compared with control subjects, which was interpreted as indicating a steeper eminence in these patients[14]. These results may be explained by the biomechanical theory of disk displacement[34], and imply that the disk must rotate further forward on the condyle during mouth opening to maintain proper contact among the disk, condyle and eminence. On the contrary, some studies[17,20] found no such correlation between TMJ disk displacement and steepness of the eminence. In fact, one report showed a reverse correlation between TMJ disk displacement and steepness of the eminence[16]. However, the steepness of the eminence has not been studied with respect to the overall patterns of the condylar positioning during clenching. A study reported by Pullinger et al.[21] may be the only study which gives a reason for the difference of the rigidity of the condylar positioning in relation to the steepness of the eminence. They indicated a negative correlation between a steeper eminence and the overlying articular soft tissue thickness. It is expected that the difference of the soft tissue thickness depending upon the steepness of the eminence might be of particular significance for determining the rigidity of the condylar positioning.

This study supports the hypothesis that the steepness of the articular eminence is an important factor in condylar positioning during clenching. The present results may have important implications on clinical procedures, such as treatment planning of partially edentulous cases without posterior occlusal supports.

CONCLUSIONS

The following conclusions are proposed regarding the relationship between the steepness of the articular eminence and the condylar positioning during clenching.

- A significant negative correlation was observed between the sagittal condylar guide inclination and the distance of ipsilateral condylar positioning.
- This result suggests that the steepness of the articular eminence is an important factor in condylar positioning during clenching.

MANUFACTURES' DETAILS

- FASTRAK, Polhemus Inc, Vermont, USA
- PLASTER LOCK , Morita Inc, Tokyo, Japan

ADDRESS FOR CORRESPONDENCE

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