Original Article

Dentofacial characteristics in orthodontic patients with centric relation–maximum intercuspation discrepancy

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ABSTRACT

Introduction: To investigate dentofacial characteristics of orthodontic patients with centric relation (CR)–maximum intercuspation (MI) discrepancy and to analyze changes in dentofacial characteristics between CR and MI positions in these patients using lateral cephalograms.

Materials and Methods: Adult female patients were classified into two groups: large CR-MI discrepancy (greater than 2.0 mm horizontal or vertical mandibular incisor movements during CR to MI change, n = 20) and small CR-MI discrepancy (less than 1.0 mm horizontal and vertical mandibular incisor movements during CR to MI change, n = 22). All subjects underwent temporomandibular joint (TMJ) magnetic resonance imaging prior to treatment. Gnathological stabilizing splints were used to find a reliable CR position in patients with large CR-MI discrepancy. Sixteen variables from lateral cephalograms were analyzed to identify differences in cephalometric variables between CR and MI positions in patients with large discrepancy. Differences in dentofacial cephalometric variables at MI positions between patients with large and small CR-MI discrepancies were also analyzed.

Results: Patients with large CR-MI discrepancy had backward positioning and rotation of the mandible at the MI position compared to the norm. In addition, the mandible moved more posteriorly and rotated more in a clockwise direction during MI to CR change. Interestingly, all patients with large CR-MI discrepancy had TMJ disk displacement. There were no significant differences in the cephalometric variables of the MI positions between patients with small and large CR-MI discrepancies.

Conclusions: This study suggests that adult patients with backward positioning and rotation of the mandible should be carefully evaluated as a result of the potential CR-MI discrepancy. (*Angle Orthod.* 2014;84:939–945.)

KEY WORDS: Centric relation; Maximum intercuspation; Orthodontic patients

INTRODUCTION

The importance of centric relation (CR) and maximum intercuspation (MI) has been an issue of continual argument in orthodontics. Since these two specific concepts are the basis for the accurate diagnostic step in orthodontic treatment, it is important to analyze and understand the CR and MI positions. The *Glossary of Prosthodontic Terms* defines CR as "the maxillary-mandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective disks with the condyle in the anterior-superior position against the slopes of the articular eminence."[1] MI is defined as "the complete intercuspation of the opposing teeth independent of condylar position."[1] CR is the beginning of occlusion and the basis for all treatment modalities.[2] If the occlusion is not stable in the CR position, shifting will occur from the CR positions to a more stable MI

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position. This shifting is called the CR-MI discrepancy. Many studies[3,4] have reported that most patients show a discrepancy between CR and MI. A small discrepancy of less than 1.0 mm in the vertical or horizontal plane is epidemiologically normal and apparently not a risk factor for temporomandibular disorder (TMD).[5] However, a greater than 2.0-mm slide from CR to MI in the vertical or horizontal plane is a critical factor that needs to be considered when assessing relative risk factors for TMD.

The CR-MI discrepancy can be observed in routine clinical practice, but an occlusal analysis with articulator-mounted casts is necessary for a more precise evaluation of the magnitude and direction of the discrepancy.[6] However, the instrumentation and procedure errors that occur during CR and MI bite registrations, face-bow transfer, the mounting of casts, and the use of average values for the hinge axis must be considered when using an articulator. In addition, obtaining an accurate head film in CR after CR and MI registrations on the articulator is not always successful, although Slavicek[7] developed a technique permitting the transfer of an MI tracing onto a CR tracing.

The presence of CR-MI discrepancy significantly interferes with the orthodontic diagnostic process by changing the characteristics of the malocclusions initially observed at the MI position. If orthodontic diagnosis is based on the true CR position, orthodontic treatment of patients with CR-MI discrepancy will apparently be successful through proper diagnosis. Although many researchers[5,7,8] have investigated CR-MI discrepancy at the condylar level using an articulator, few studies have analyzed CR-MI discrepancy at the incisor level using lateral cephalograms, a method that may be more simply and efficiently applicable to clinical orthodontics. The purpose of this study was to investigate dentofacial characteristics of patients with horizontal or vertical mandibular incisor movements greater than 2.0 mm during CR to MI changes using lateral cephalograms. We also sought to analyze changes in dentofacial characteristics between CR and MI positions in these patients. Additionally, we evaluated the results of temporomandibular joint (TMJ) magnetic resonance imaging (MRI) according to the presence of CR-MI discrepancy.

MATERIALS AND METHODS

The sample for this study consisted of women seeking orthodontic treatment. Exclusion criteria were (1) age less than 17 years, (2) any systemic disease, (3) history of orthodontic treatment or orthognathic surgery, (4) history of trauma involving the TMJs, (5) juvenile rheumatoid arthritis, and (6) history of TMJ treatment.

We recruited subjects with CR-MI discrepancy. CR-MI discrepancy was determined according to a modification of the method described previously.[9] The condyles were guided to their most anterosuperior position in the fossa using a bilateral mandibular guiding technique with the patients in the supine position, and the jaw was passively manipulated to the first tooth contact.[10] With the aid of a ruler, and compared to the position of the maxillary central incisors, the magnitude of movement of the mandibular central incisors from CR to MI was visually assessed at the sagittal and vertical planes. Patients with CR-MI discrepancy were defined as those who had an incisor region discrepancy measuring greater than 1.0 mm in the horizontal or vertical plane. All subjects with CR-MI discrepancy consented to both a routine lateral cephalogram at the MI position and a bilateral high-resolution MRI in the sagittal (opened and closed) and coronal (closed) planes in order to evaluate the TMJ. The research protocol was approved by the institutional review board of the Seoul National University Dental Hospital.

Acrylic gnathological stabilizing splints were used in patients with CR-MI discrepancies to find reliable CR positions through muscle deprogramming.[11,12] An anterior acrylic lamp was inserted into the splints at a 30–45° angle to the occlusal plane to allow a mutually protected occlusal scheme.[1] The patients were instructed to wear the splints for 24 hours a day.

The patients wearing the stabilization splints were asked to return 7 days after the first splint delivery. At that time, the occlusal marks on the splint and the signs and symptoms of TMJ were determined. When the changes existed in the occlusal contacts, the splint was adjusted to optimum occlusal conditions for mutually protected occlusion. The occlusal and TMJ examinations were then repeated every 4 weeks after initial examination. The splints were applied to patients for at least 3 months, until occlusion was stabilized at the CR position. In the case of patients with specific clinical signs or symptoms of TMJ, the splints were applied until clinical signs and symptoms were completely resolved.

After stabilization of the CR position, lateral cephalograms were taken in the CR position. A single investigator traced all CR and MI cephalograms. Fifteen landmarks (Figure 1) were digitized on each radiograph, from which 16 cephalometric variables (Figures 2 and 3) were calculated. The subjects who had greater than 2.0 mm of horizontal or vertical mandibular incisor movements between the CR and MI positions were classified as having a large CR-MI discrepancy (20 subjects). The group with small CR-MI discrepancy (the control group) was composed of 27 female patients with less than 1.0 mm of horizontal and

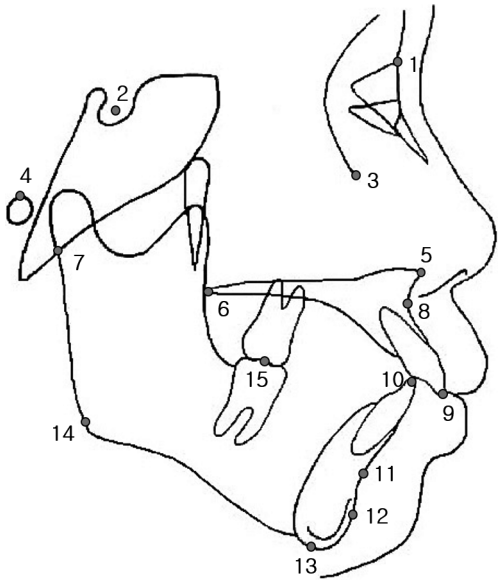

Figure 1. Landmarks used in this study: 1, nasion; 2, sella; 3, orbitale; 4, porion; 5, anterior nasal spine; 6, posterior nasal spine; 7, articulare; 8, point A; 9, incisal end of maxillary incisor; 10, incisal end of mandibular incisor; 11, point B; 12, pogonion; 13, menton; 14, gonion; and 15, articulation of maxillary and mandibular molars.

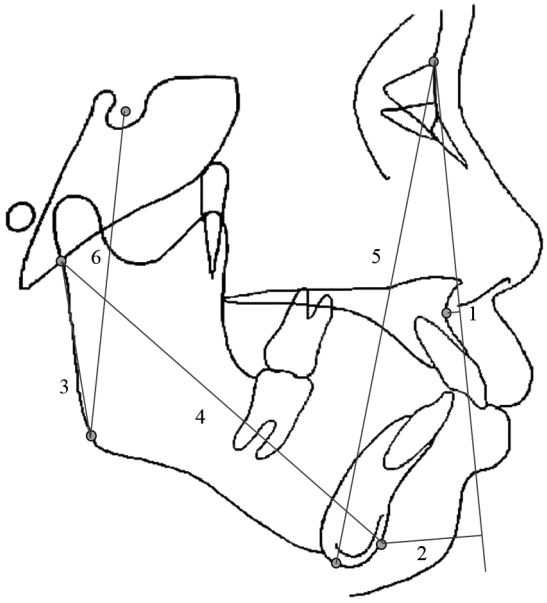

Figure 3. Linear measurements used in this study: 1, N perpendicular to point A; 2, N perpendicular to pogonion; 3, ramus height; 4, effective mandibular length; 5, total anterior facial height; and 6, total posterior facial height.

vertical mandibular incisor movement during CR to MI changes. High-resolution TMJ MRIs were taken in patients in the control group to evaluate TMJ status due to the presence of clinical signs and symptoms.

Two radiologists with experience in interpreting TMJ in MRIs interpreted the MRIs without knowledge of the clinical status of the patients. The positions of the TMJ disks were evaluated according to the following classification criteria[13]: normal disk position, disk displacement (DD) with reduction, and DD without reduction.

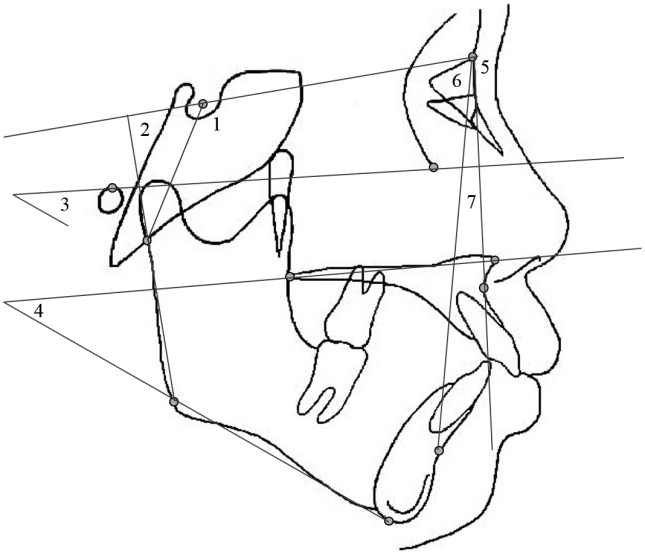

Figure 2. Angular measurements used in this study: 1, saddle angle; 2, ramus inclination; 3, FH to mandibular plane angle; 4, maxillomandibular plane angle; 5, SNA angle; 6, SNB angle; and 7, ANB angle.

Fifteen subjects were randomly chosen from the total sample, and their lateral cephalograms were measured again to estimate measurement error for the present study. The reliability of the tracing, landmark identification, and analytical measurements all had intraclass correlation coefficients that were greater than 0.98.

The Wilcoxon signed rank test was used to determine any significant differences in dentofacial morphology between the CR and MI positions in patients with large CR-MI discrepancy. The Mann-Whitney *U*-test was used to determine any significant differences in dentofacial morphology at the MI position between patients with large and small CR-MI discrepancies. Values were considered statistically significant at $P < .05$.

RESULTS

A total of 47 patients (27 in the small CR-MI discrepancy group, 20 in the large CR-MI discrepancy group) were selected (Table 1). There was no significant difference in the age distribution between the two groups. CR stabilization splints were used for an average of 6.6 $\pm$ 5.5 months in patients with large CR-MI discrepancy.

Table 2 shows the distribution of patients according to TMJ DD status. All patients with large CR-MI

Table 1. Age (Years) Distribution of Patients with Small (n = 27) and Large (n = 20) Centric Relation–Maximum Intercuspation (CR-MI) Discrepancies[a]

	Small CR-MI Discrepancy, Mean (SD)	Large CR-MI Discrepancy, Mean (SD)
Age, y	25.9 (7.2)	24.7 (6.5)

[a] SD indicates standard deviation.

discrepancy had TMJ DD, mainly bilateral TMJ DD (19 of 20 patients).

Comparisons of the dentofacial characteristics between the CR and MI positions in patients with large CR-MI discrepancy are found in Table 3. Fourteen of the 16 cephalometric variables showed significant differences between the CR and MI positions. The differences were mainly associated with changes in mandibular position. The CR tracings showed increased ANB, ramus inclination, and saddle angle and decreased N perpendicular to pogonion, total anterior facial height to posterior facial height ratio, and effective mandibular length compared to the MI tracings, indicating that the mandible was positioned more posteriorly and rotated more in a clockwise direction in the CR position than in the MI position. With regard to the dental relationship, increased overjet and decreased overbite were observed during CR to MI changes. However, variables associated with the maxilla (SNA and N perpendicular to point A) did not show any significant changes between CR and MI positions.

Generally, TMJ DD is associated with specific dentofacial characteristics, such as decreased posterior facial height and backward positioning and rotation of the mandible.[13–15] Therefore, we only included patients with TMJ DD to evaluate differences in dentofacial characteristics between patients with large and small CR-MI discrepancies, excluding the effect of TMJ DD on dentofacial characteristics (Table 4). No dentofacial characteristics were significantly different for the MI position between patients with large and small CR-MI discrepancies, although all the patients included in this study showed backward positioning and rotation of the ramus and mandible compared to the Korean norm (Tables 3 and 4).

DISCUSSION

This study showed an association between large CR-MI discrepancy and TMJ DD, although the cause-effect relationship is unclear. TMJ DD may cause large CR-MI discrepancy, or TMJ DD may occur as a consequence of large CR-MI discrepancy. Nevertheless, these results suggest that large CR-MI discrepancy may be one of the contributing factors to TMJ DD because all patients with TMJ DD did not have large CR-MI discrepancy, but all patients with large CR-MI discrepancy had variable TMJ DD on at least one side of the TMJ, with most having bilateral TMJ DD (Table 2). These findings are supported by previous studies[16,17] reporting that CR-MI discrepancy of greater than 2.0 mm increases the risk of intracapsular disorders, because CR-MI discrepancy induces a shift between the disk and condyle and can lead to strain on the discal ligaments and eventual elongation of the discal ligaments and thinning of the disk. Osteoarthritis or condylar resorption is commonly accompanied by TMJ DD.[18] The form and shape of the TMJ become abnormal during arthritic changes, which may induce CR-MI discrepancy. Premature contact during closure in the CR might be a trigger point for parafunctional activities such as clenching and bruxism. Such parafunctional activities probably have a far greater potential for injury than does any other purely functional activity.[6]

Although the definitions of CR have evolved over several decades, the CR position in patients with large CR-MI discrepancy is not satisfyingly defined by the following definition: ''the condyles articulate with the thinnest avascular portion of their respective disks.'' We feel this definition is inadequate because all patients with large CR-MI discrepancies in this study had TMJ DD. Although there are other definitions of CR that do not define the positional relationships between disk and condyle,[1] the term ''mandibular hinge position'' or ''guided centric position'' may be more acceptable than CR in these patients with large CR-MI discrepancies. In the present study, in order to avoid confusion we used the term CR to denote the

Table 2. The Distribution (No.) of Patients with Small and Large Centric Relation–Maximum Intercuspation (CR-MI) Discrepancies According to Temporomandibular Joint (TMJ) Disk Displacement Status

	Group 1[a]	Group 2[b]	Group 3[c]	Group 4[d]	Group 5[e]	Group 6[f]	Total
Small CR-MI discrepancy	5	8	2	0	6	6	27
Large CR-MI discrepancy	0	0	5	1	5	9	20

[a] Bilateral normal TMJs.
[b] Unilateral disk displacement with reduction and normal contralateral TMJ.
[c] Bilateral disk displacement with reduction.
[d] Unilateral disk displacement without reduction and normal contralateral TMJ.
[e] Unilateral disk displacement with reduction and disk displacement without reduction in the contralateral TMJ.
[f] Bilateral disk displacement without reduction.

Table 3. Comparison of Changes in Dentofacial Characteristics of Patients (n = 20) with a Large Centric Relation–Maximum Intercuspation (CR-MI) Discrepancy Between the CR and MI Positions[a]

Variables	Korean Norm, Mean (SD)	CR, Mean (SD)	MI, Mean (SD)	Significance[b]
Maxillo-mandibular relationship				
SNA, °	81.1 (3.7)	81.6 (4.1)	81.7 (4.0)	NS
SNB, °	78.0 (3.8)	73.9 (3.9)	75.6 (3.9)	***
N perpendicular to point A, mm	0.4 (2.3)	1.4 (4.0)	1.5 (3.9)	NS
N perpendicular to pogonion, mm	−1.8 (4.5)	−12.4 (7.9)	−8.1 (8.2)	***
ANB, °	3.5 (1.9)	7.7 (2.4)	6.0 (2.5)	***
Vertical skeletal relationship				
FMA, °	29.6 (5.7)	34.3 (6.0)	31.3 (6.5)	***
Maxillo-mandibular plane angle, °	28.4 (5.2)	33.3 (6.2)	30.6 (5.7)	***
Total anterior facial height, mm	128.7 (6.3)	134.6 (4.7)	132.9 (5.0)	**
Total posterior facial height, mm	82.8 (5.3)	80.7 (5.5)	81.3 (6.0)	*
Total anterior facial height/total posterior facial height, %	65.3 (8.8)	60.1 (4.8)	61.2 (5.2)	**
Size and form of mandible				
Ramus height, mm	49.1 (4.9)	46.2 (3.6)	48.6 (5.8)	**
Ramus inclination, °	93.1 (5.2)	102.9 (6.0)	100.2 (6.5)	***
Effective mandibular length, mm	113.4 (6.7)	108.3 (5.2)	110.3 (5.3)	***
Saddle angle, °	123.8 (4.8)	125.8 (5.4)	125.0 (5.8)	*
Dental relationship				
Overbite, mm	1.8 (1.1)	−2.3 (3.8)	0.6 (3.3)	***
Overjet, mm	3.5 (1.0)	7.1 (1.8)	5.1 (2.0)	***

[a] SD indicates standard deviation; NS, not significant; * $P < .05$; ** $P < .01$; *** $P < .001$.

[b] The Wilcoxon signed rank test was performed to analyze for changes in the dentofacial characteristics between CR and MI at a significance level of $\alpha = .05$.

Table 4. Comparisons of the Dentofacial Characteristics Between Patients with Small (n = 22) and Large (n = 20) Centric Relation–Maximum Intercuspation (CR-MI) Discrepancies[a]

Variables	Korean Norm, Mean (SD)	Small CR-MI Discrepancy, Mean (SD)	Large CR-MI Discrepancy, Mean (SD)	Significance[b]
Maxillo-mandibular relationship				
SNA, °	81.1 (3.7)	81.9 (3.8)	81.7 (4.0)	NS
SNB, °	78.0 (3.8)	77.3 (4.9)	75.6 (3.9)	NS
N perpendicular to point A, mm	0.4 (2.3)	1.8 (3.4)	1.5 (3.9)	NS
N perpendicular to pogonion, mm	−1.8 (4.5)	−5.8 (9.0)	−8.1 (8.2)	NS
ANB, °	3.5 (1.9)	4.6 (3.1)	6.0 (2.5)	NS
Vertical skeletal relationship				
FMA, °	29.6 (5.7)	30.4 (5.5)	31.3 (6.5)	NS
Maxillo-mandibular plane angle, °	28.4 (5.2)	31.3 (7.5)	30.6 (5.7)	NS
Total anterior facial height, mm	128.7 (6.3)	133.4 (5.8)	132.9 (5.0)	NS
Total posterior facial height, mm	82.8 (5.3)	82.9 (6.3)	81.3 (6.0)	NS
Total anterior facial height/total posterior facial height, %	65.3 (8.8)	62.3 (5.3)	61.2 (5.2)	NS
Size and form of mandible				
Ramus height, mm	49.1 (4.9)	48.5 (4.5)	48.6 (5.8)	NS
Ramus inclination, °	93.1 (5.2)	99.5 (7.1)	100.2 (6.5)	NS
Effective mandibular length, mm	113.4 (6.7)	111.4 (5.7)	110.3 (5.3)	NS
Saddle angle, °	123.8 (4.8)	123.3 (5.6)	125.0 (5.8)	NS
Dental relationship				
Overbite, mm	1.8 (1.1)	1.2 (3.2)	0.6 (3.3)	NS
Overjet, mm	3.5 (1.0)	4.6 (2.5)	5.1 (2.0)	NS

[a] SD indicates standard deviation; NS, not significant.

[b] The Mann-Whitney *U*-test was performed to analyze for changes in the dentofacial characteristics at the MI position between patients with large and small CR-MI discrepancies at a significance level of $\alpha = .05$.

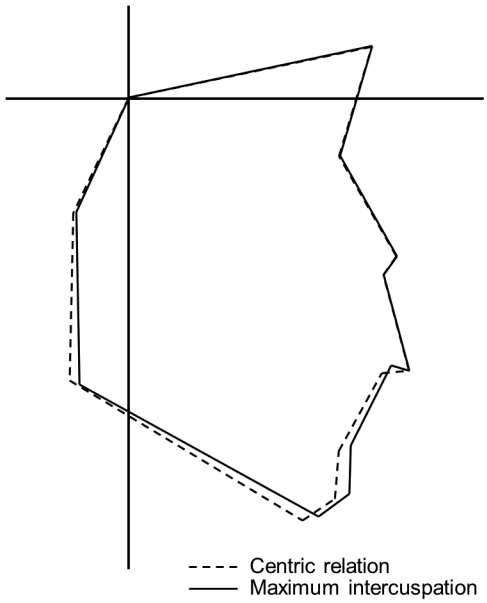

Figure 4. Comparison of skeletal profilograms between centric relation (CR, dotted line) and maximum intercuspation (MI, solid line) positions in patients with larger CR-MI discrepancy.

maxillary-mandibular relationship whereby the condyles are located in the anterior-superior position against the slopes of the articular eminence, regardless of the disk position.

The present study showed that patients with large CR-MI discrepancy had specific dentofacial characteristics, such as decreased SNB, N perpendicular to pogonion, and ramus height and increased ANB and ramus inclination in both CR and MI positions compared to the Korean norm (Table 3). This means that patients with large CR-MI discrepancy had backward positioning and rotation of the ramus and mandible. Previous studies[13,14] have reported that patients with TMJ DD are more likely to have a specific skeletal morphology, including decreased ramus height and posterior facial height, and clockwise rotation of the ramus and mandible, indicating that DD is associated with skeletal Class II and hyperdivergent skeletal patterns. Given that all patients with large CR-MI discrepancy had TMJ DD, specific dentofacial characteristics of patients with large CR-MI discrepancy may result from altered morphologies associated with TMJ DD.

This study demonstrated that patients with large CR-MI discrepancy showed significant changes in mandibular position during CR to MI changes (Table 3; Figure 4). The patients with large CR-MI discrepancy had a larger ANB and overjet and a steeper mandibular plane and ramus inclination in the CR position than in the MI position. This implies that skeletal morphology in the MI position of patients with large CR-MI discrepancy changes to a more retruded mandible and a more hyperdivergent skeletal pattern in the CR position. These results are confirmed by the findings of previous studies[4,8,19] that showed that most patients with CR-MI discrepancy demonstrate vertical and anterior movement of the mandible between the CR and MI positions. As a result, original Class II occlusion with hyperdivergent facial patterns in the MI position may be exacerbated in the CR position, which may in turn increase treatment difficulty and lead to the need for orthognathic surgery (as opposed to orthodontic treatment alone) in patients with large CR-MI discrepancy. The large CR-MI discrepancy may not result from the splint application, because the splint did not significantly influence mandibular position (less than 1.0 mm in the sagittal and vertical plane during CR to MI change) when applied in eight patients with small CR-MI discrepancy (data not shown).

Although there were significant differences in the dentofacial characteristics of patients with large CR-MI discrepancy between the CR and MI positions, there were no significant differences in dentofacial characteristics at the MI position between patients with small and large CR-MI discrepancies when only patients with TMJ DD were included (five patients who had bilateral normal disk position were excluded; Table 2). This may be due to the fact that TMJ DD is associated with skeletal Class II with hyperdivergent patterns,[13,14,20] and all the patients included in this study had TMJ DD, regardless of CR-MI discrepancy. All of these findings suggest that it is not easy to discriminate between patients with large CR-MI discrepancy and those with small CR-MI discrepancy only in the MI position.

There is no doubt that the CR is considered the most acceptable condylar and occlusal position on which to base reorganization of orthodontic treatment.[2] Considering that the presence of CR-MI discrepancy can mask a more severe malocclusion, it is necessary to mount casts of patients with potential CR-MI discrepancy on an articulator in order to diagnose the malocclusion. However, it would be too laborious to mount every cast to evaluate CR-MI discrepancy. In this regard, it may be useful for orthodontists to screen patients with potential CR-MI discrepancy before mounting casts. This study suggests that adult patients with backward positioning and rotation of the mandible should be carefully evaluated as a result of their potential CR-MI discrepancy and/or TMJ DD.

This study had some limitations. First, the sample size was small. It was difficult to recruit subjects who had greater than 2.0 mm of mandibular incisor movement during the CR to MI change and who had undergone TMJ MRI. In addition, only adult females were selected as subjects to avoid both gender-related and growth-related effects. Second, we did not evaluate lateral slides during the CR to MI change.

Although the prevalence of lateral movements from CR to MI is significantly lower than that of either antero-posterior or vertical mandibular movement,[3,4] slides that deflect the mandible to the left or right are more commonly associated with dysfunction than are slides that create a straight antero-vertical movement.[4] Further studies using a larger sample size with lateral CR-MI slides are needed to better understand the clinical implications of the relationships between CR-MI discrepancy and dentofacial characteristics.

CONCLUSIONS

- Patients with large CR-MI discrepancy had TMJ DD.
- Patients with large CR-MI discrepancy had backward positioning and rotation of the mandible in the MI position compared to the norm.
- In patients with large CR-MI discrepancy, the mandible moved more posteriorly and rotated more in a clockwise direction during the CR to MI change.
- There were no significant differences in the dentofacial characteristics in the MI position between patients with small and large CR-MI discrepancies.

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