# The Difference in Condylar Position Between Centric Relation and Centric Occlusion in Pretreatment Japanese Orthodontic Patients

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Abstract: This study investigates the differences in condylar position between centric relation (CR) and centric occlusion (CO) in Japanese orthodontic patients before treatment. We employed 150 consecutive cases (age range: 6-57 years) for the study. Dental casts were mounted on a Panadent articulator with a power centric CR bite record. The differences in condylar position between CR and CO in all three spatial planes were measured using the Panadent Condyle Position Indicator (CPI). The subjects were divided into groups by age, gender, mandibular plane angle or angle classification. No significant differences in the magnitude of CPI measurements were found among the groups. The three-dimensional distances of condylar displacement on both sides were almost identical, and the superoinferior displacement (S-I) was greater (P < .0001) than the anteroposterior displacement (A-P). The S-I was greater (P = .02) on the left side than on the right side, while the A-P displacement was smaller (P < .0001) on the left side than that on the right side. Significant condylar displacement (2.0 mm for S-I and A-P, 0.5 mm for the lateral displacement, L) was found frequently in L (31.3%), S-I, and A-P, in that order. Fifty-eight (38.7%) of the subjects had significant displacement in L, S-I, or A-P. Moreover, Angle Class III subjects tended to have significant condylar displacement toward the left side. The results suggest that orthodontists should be aware of a high incidence of condylar displacement in Japanese orthodontic patients and measure condylar displacement before the start of comprehensive orthodontic treatment to unmask real jaw relationships and avoid possible misdiagnoses. (Angle Orthod 2002;72:295-301.)

Key Words: Variability of condylar position; CPI; Japanese; Asymmetry

## INTRODUCTION

There are numerous studies showing that the ideal sagittal position of the condyle is forward and uppermost against the eminence when the joint is loaded by the elevating musculature.<sup>1–9</sup> These findings encourage orthodontists to employ this condylar position (CR) as a treatment goal. The condylar position is directly related to how the teeth come together because the condyles and the teeth are connected with each other and move in tandem. Therefore,

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due to malocclusions, the condyles may not be located in CR in orthodontic patients before treatment. To provide a proper treatment plan, the condylar position must be evaluated and a determination of CR is a reasonable prerequisite for the analyses of occlusion and jaw relationship.

Some researchers have commented that a difference in condylar position between the patient's full or habitual occlusion (centric occlusion: CO) and CR would cause temporomandibular dysfunction (TMD).<sup>10,11</sup> On the other hand, while looking for a possible relationship between occlusion and TMD, a number of researchers found correlations either weak or nonexistent.<sup>12-16</sup> However, this could be because they had examined dental conditions such as overbite and overjet, which are poor indicators of condylar position.<sup>17,18</sup> Recently, a high correlation (P < .001) between the sign and symptom of TMD and the Panadent Condyle Position Indicator (CPI) value has been documented (ie, there is a relationship between TMD and unfavorable condylar position determined by the occlusion).<sup>19</sup> Accordingly orthodontic treatment, which keeps the condyles in CR, would reduce the risk of TMD.

Several studies have shown that in most cases, the neu-

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romuscular system positions the mandible to achieve maximum intercuspation regardless of the condylar position in the fossae.<sup>20,21</sup> When occlusal interferences are present, mechanoreceptor feedback from the periodontal fibers surrounding the involved teeth program muscle function to avoid the interferences and this masks the discrepancy.<sup>22,23</sup> Ackerman and Proffit<sup>24</sup> recommended that the point of initial contact should be used to assess the occlusion when there is a shift of more than 1 to 2 mm between maximum intercuspation and the point of initial tooth contact in CR closure. Proffit<sup>25</sup> stated further that lateral shifts of any magnitude, or forward shifts of 2 or 3 mm, should be considered significant and require mounting on an articulator. The observation of a slide or shift at the level of the occlusion may not accurately represent a three-dimensional change in position of the condylar axis.<sup>26,27</sup>

A number of clinicians recommend mounting diagnostic casts prior to treatment in order to see the difference in condylar position between CO and CR.28-32 Mounted casts allow us to observe how much of the malocclusion is accurate and how much is due to mandibular displacement.33 Taking the CR bite registration that promotes condylar seating and avoids the neuromuscular feedback could unmask a true discrepancy.<sup>2,6</sup> If this is the case, it is likely that the overjet increases and the overbite decreases; what might appear as a Class I malocclusion might be a severe Class II malocclusion, and what appears to be an Angle Class II, division 2 with deep overbite might be an anterior open malocclusion.18,34 These possible changes need careful consideration in diagnosis, especially for patients with high mandibular plane angles, retruded chins, or both. These features are often found in Japanese orthodontic patients and can alter the treatment plan for malocclusion.

To our knowledge, however, there were no reports of this amount of difference in condylar position between CR and CO in Japanese orthodontic patients. Information about norms of condylar displacement in Japanese orthodontic patients could be helpful for orthodontists in Japan and also in multiracial societies such as North America and Europe. The purposes of this study are: (1) to report the frequency, magnitude, and laterality of differences in condylar position between CO and CR before orthodontic treatment; (2) to investigate how the differences vary according to age, gender, mandibular plane angle, or Angle classification; and (3) to compare the results with those of the Caucasian race.

#### MATERIALS AND METHODS

The records of 150 patients who accepted orthodontic treatment at a clinic were employed as the study sample (45 men and boys and 105 women and girls). The average age was 15.6 years, with a range of 6.7 to 57.8 years. The patients were divided into groups by age ( $\leq 10$  years; >10 years to 18 years; > 18 years), gender, SN to mandibular plane angle ( $\leq 29^\circ$ ; >29° to 32°; >32°) or Angle classifi-

cation. To eliminate interoperator error and ensure standardization, one experienced operator managed all the technical procedures.

Maxillary and mandibular impressions were taken using an irreversible hydrocolloid in rimlock trays, and the impressions were immediately poured in type IV high-strength dental stone (Vel-Mix, Kerr Manufacturing Co, Romulus, Mich). To obtain the CR position, a power centric wax interocclusal registration<sup>1,3,4,6,18,35</sup> was taken with Delar Bite registration wax (Delar Corp, Lake Oswego, Ore) consisting of anterior and posterior sections. The anterior section, four or five layers thick, softened with a controlled water bath at 60°C, extended from canine to canine, and the posterior section, two layers thick, extended across the arch. The patient was seated in the dental chair reclined to a  $45^{\circ}$ angle, and the anterior section was placed on the upper anterior teeth. The operator guided the mandible, applying pressure at pogonion toward the condyles, supporting the angles of the mandible in a superior direction and asked the patient to close slowly to a 2-mm posterior interarch vertical separation. The wax was cooled with the air syringe, removed and placed into cold water. The hardened anterior wax was again placed over the upper anterior teeth after the softened posterior wax had been placed across the upper posterior teeth. The patient was asked to bite down firmly after closing into the hardened anterior wax, which allowed the patient's muscles to seat the condyles without occlusal interferences. The posterior wax recorded the posterior tooth indexing, and was then cooled and hardened in cold water. The CR registration wax was carefully trimmed with a scalpel blade so that only indentations for the cusp tips remained in the wax.

The CO record was obtained using a single layer of 24gauge sheet wax (Shofu Inc, Kyoto, Japan) trimmed to the dental arch form, softened in a water bath, and placed on the upper arch. The patient was then instructed to bite down firmly and to tap the teeth together. The wax was cooled with an air syringe and then removed from the mouth.

The dental casts were mounted on the articulator using fast-set mounting stone (Mounting Stone, Whip Mix Corporation, Louisville, Ky). The maxillary stone cast was mounted on the upper member of a Panadent articulator with an anatomic facebow transfer (Panadent Corp, Grand Terrace, Calif). A split cast mounting procedure was adopted toward the maxillary cast. The mandibular cast was then related to the upper one with the CR wax record. Panadent Condyle Position Indicator recordings of CR and CO were made on adhesive grid paper fixed to the sliding center platform of the CPI. The device measures the three-dimensional changes of the articulator condyles between CR and CO. The horizontal and vertical changes in the sagittal plane at the articulator condyle correspond to the x change (anteroposterior displacement, A-P) and z change (superoinferior displacement, S-I) and the transverse change corresponded to the y change (lateral displacement, L). Positive values of x, y, and z indicate that, on CO, the condyle was located in an anterior, right, and inferior position in relation to CR. The distance between the three-dimensional locations of CO and CR was designated as 'D'. All measurements of x, y, and z were recorded to the nearest 0.1 mm, using a monocular lens fitted with a magnified grid calibrated to 0.1 mm.

To determine what percentage of the sample population has a significant condylar displacement between CR and CO, a discrepancy of 2 mm or greater in the sagittal plane or 0.5 mm or greater in the transverse direction was considered clinically significant. The criteria employed in the study for judging how much discrepancy might be significant were identical to those of Utt et al.<sup>29</sup>

In each group, each variable was tested for a normal distribution with a Chi-square test, and the homogeneity of all variances was tested with a Bartlett test. The results of the tests determined which statistical analysis to perform next. The Kruskal-Wallis test was used to identify differences among the three groups classified by age, gender, or Angle classification. A Wilcoxon signed rank test was used to determine significant differences between two groups and to determine significant deviation from zero. Pearson's correlation coefficient was calculated between the parameters to identify possible correlation between CPI measurements and age, gender, SN to mandibular plane angle, ANB angle, or Angle classification. A value of R > 0.7 was considered a strong correlation. The data were presented as the mean  $\pm$  standard deviation (SD) and tests were performed by a statistical analysis software program (StatView IV, Abacus Concepts Inc, Berkeley, Calif) with a value of P < .05 as statistically significant.

#### RESULTS

No significant differences in the magnitude of CPI measurements were found among any set of groups, which were divided according to age, gender, mandibular plane angle, or Angle classification (Table 1). S-I on the left side was greater than that on the right side (P = .02), while A-P on the left side was smaller than that on the right side (P <.0001). On both sides, the amount of S-I was greater than that of A-P (P < .0001). The three-dimensional distances of condylar displacement on both sides were nearly identical to each other. The condylar distraction from CR to CO was primarily in a downward direction with a smaller A-P component. Significant displacement (2.0 mm for S-I and A-P, 0.5 mm for L) was found frequently in L, S-I, and A-P, in that order (Table 2). Forty-seven patients (31.3%) displayed a lateral shift of 0.5 mm or more. Twenty-four patients (16.0%) had significant condylar displacement on at least one side in the sagittal plane, S-I, or A-P. Fiftyeight patients (38.7%) had significant displacement on at least one side in L, S-I, or A-P. Four patients (2.7%) had significant sagittal discrepancy bilaterally. Thirteen individ-

TABLE 1. Condylar Displacement in Centric Occlusion

	$\text{Mean}\pm\text{SD}$	Range			
Lateral	$0.0\pm0.5$	-1.0 to 2.1			
	Lef	t	Right		
	$\text{Mean} \pm \text{SD}$	Range	$\text{Mean} \pm \text{SD}$	Range	
S—I^ А—Р <sup>в</sup> D <sup>с</sup>	$\begin{array}{c} 1.0\pm0.7\ddagger^{*}\\ -0.1\pm0.8\\ 1.4\pm0.8\ddagger\end{array}$	-0.4 to 3.4 -1.7 to 5.0 0.2 to 5.3	$\begin{array}{l} 0.9\ \pm\ 0.7 \ddagger^* \\ 0.2\ \pm\ 0.8 \ddagger \\ 1.3\ \pm\ 0.6 \ddagger \end{array}$	-1.0 to 3.0 -1.8 to 3.2 0.2 to 3.4	

*S–I* indicates superioinferior component of condylar displacement; A-P, anteroposterior component of condylar displacement; and *D*, 3-dimensional distance of condylar displacement.

+ P < .01 (Wilcoxom signed rank test) for the deviation from zero.

P < .001 (Wilcoxom signed rank test) for the deviation from zero. \* P < .0001 (Wilcoxon signed rank test) for the difference in S-I and A-P.

^ P = .0206 (Wilcoxon signed rank test) for the difference in *S*-*I* between the left and right sides.

<sup>B</sup> P < .0001 (Wilcoxon signed rank test) for the difference in A-P between the left and right sides.

 $^{\rm c}$  P = .5713 (Wilcoxon signed rank test) for the difference in the three-dimensional distance between the left and right sides.

**TABLE 2.** The Frequency of Significant Displacement of Condyle in

 Centric Occlusion

		Significant	NI	0/
		Displacement	N	%
[1] <i>S–I</i>	Left	≥2.0 mm	14	9.3
[2] <i>S–I</i>	Right	≥2.0 mm	11	7.3
[3] <i>A–P</i>	Left	≥2.0 mm	1	0.7
[4] <i>A–P</i>	Right	≥2.0 mm	2	1.3
[5] Latera	1	≥0.5 mm	47	31.3
[1] or [2]			21	14.0
[3] or [4]			3	2.0
[1], [2], [3] or [4]			24	16.0
[1], [2], [3], [4] or [5]			58	38.7
([1] or [3]	) and ([2] or [4])		4	2.7
([1], [2], [3	3] or [4]) and [5]		13	8.7

N indicates number of patients.

uals (8.7%) experienced significant condylar displacement in both the transverse and sagittal planes.

The magnitude of lateral displacement, the most prevalent displacement (Table 2), is summarized in Table 3. No significant difference was observed among groups classified by age, gender, or Angle classification. The mean was around zero except for the Angle Class III group in which a significant displacement of 0.2 mm toward the left side was found (P < .01). The strongest correlation was found between D, and S-I on the ipsilateral side, but there was very little, if any, correlation between other measurements (Table 4). S-I and A-P correlated positively with the corresponding displacement on the opposite side, respectively. L correlated positively with the A-P on the left side and negatively with the A-P and S-I on the right side, indicating that lateral condylar shift towards the right side tended to bring the right condyle upward and backward and the left

Age <sup>A</sup>	≤10 yrs	Ν	10 yrs<, ≤18 yrs	Ν	18 yr<	Ν			
_	0.0 $\pm$ 0.4; –0.9 to 1.0	53	0.1 $\pm$ 0.5; -0.7 to 2.1	64	$-0.1 \pm 0.4; -1.0$ to 0.7	33			
Angle classification <sup>B</sup>	Ι	Ν	II	Ν	<b>   </b> †	Ν			
_	0.1 $\pm$ 0.5; –0.7 to 1.2	44	0.0 $\pm$ 0.5; -1.0 to 2.1	84	$-0.2 \pm 0.3; -0.9$ to 0.2	22			
Gender <sup>c</sup>	Male	Ν	Female	Ν					
_	0.0 $\pm$ 0.2; –0.9 to 0.7	45	$0.0 \pm 0.2; -1.0$ to 2.1	105	-				

TABLE 3. Lateral Displacement of Condyle in Centric Occlusion (Mean  $\pm$  SD; Range, mm)

SD indicates standard deviation, and N, number of patients.

 $^{A}P = .281$  (Kruskal-Wallis test) for the difference among the groups.

<sup>B</sup> P = .147 (Kruskal-Wallis test) for the difference among the groups.

 $^{c}P = .693$  (Wilcoxon signed rank test) for the difference.

+ P < .01 (Wilcoxon signed rank test) for the deviation from zero.

condyle forward. To put it another way, a lateral condylar shift toward the left side tended to bring the right condyle downward and forward and to locate the left condyle backward. A negative correlation was found between *S*-*I* and *A*-*P*, indicating that downward condylar displacement tended to bring the condyle backward.

#### DISCUSSION

The importance of condylar position in orthodontic treatment has recently been recognized, with recommendations that study casts be mounted on an articulator in CR to diagnose malocclusions although the majority of cases can be diagnosed with hand-held casts.<sup>31,32,34,36</sup> The condylar axis can also be influenced by the occlusion,<sup>19</sup> which was not detected in earlier studies using radiograms rather than an appropriate measuring device like the CPI. The CPI was designed to record the condylar axis position in all three spatial planes, and its accuracy and repeatability have been confirmed.<sup>19</sup> On the other hand, the validity of tomographic radiographic tracings to measure small changes in condylar position has been questioned.<sup>37</sup>

It has been suggested that the condylar position in CO should coincide with CR if possible.<sup>20,39</sup> Cacchiotti<sup>38</sup> found that the MPI-measured CR-CO discrepancies of patients with TMJ complaints were significantly larger than those of a control group consisting of noncomplaining dental students. Girardot,<sup>3</sup> using the MPI, found that the condyles were displaced inferiorly in the majority of TMD patients and that symptoms were alleviated as the condyles moved toward a more seated position (CR). Further, it was reported that an increase of CPI value from 1 to 2 mm aggravate symptoms of TMD dramatically,<sup>19</sup> suggesting that one goal of treatment should be to minimize the difference of condylar position between CR and CO. Frequency, magnitude, or direction of CO-CR changes at the condylar level could not be predicted by age, gender, Angle classification, ANB angle, or mandibular plane angle, in accord with the study of Utt et al.29 Further, dispersion of the magnitude and direction of condylar displacement would mask a real jaw relationship.

In orthodontics, therefore, condyle displacement should be measured before the start of comprehensive orthodontic treatment to diagnose the occlusion and jaw relationship more accurately. Mounting dental casts in CR is helpful to show discrepancies and may reveal a malocclusion more obviously than might be seen when the teeth are in CO.<sup>29,31,32,40</sup> The mandibular body and dentition can move distally causing an increased overjet, a decreased overbite, and a change from an Angle Class I molar relationship to a Class II relationship.<sup>18</sup> In this situation, treatment plans should be made from CR.<sup>17,18,31,41</sup>

A "power centric" wax interocclusal registration will capture CR, and its high reproducibility has been reported elsewhere.<sup>18</sup> In the presence of occlusal interferences, muscles may change jaw position to prevent excessive occlusal force on the teeth.<sup>42</sup> The deviated pattern of closure is memorized, and the patterns of muscle activity, called muscle splinting, might prevent detection of interferences.<sup>43</sup> It could also prevent the condyles from seating during CR registration.<sup>31,44,45</sup> Therefore, the subject should be deprogrammed from the habitual CO to capture CR. For this purpose, mandibular repositioning splints are often employed. However, in orthodontic treatment, this was frequently impractical due to the longterm wearing of splints.

The power-centric registration developed by Roth refers to the use of the patient's jaw-closing muscles and an anterior stop. The anterior stop enables the musculature to seat the condyles in an anterosuperior direction during the CR recording.<sup>1,3,4,6,35</sup> The technique was developed to obtain the best-seated condylar position possible on the day of registration, and its effectiveness has been documented.<sup>4,18</sup> In the present study, therefore, it would be reasonable to assure that the effect of muscle splinting would have been minimized.

Considerable bilateral asymmetry of condylar displacement was confirmed in this study. In earlier studies using the MPI or CPI system,<sup>29,46,47</sup> it was not clear, for lack of statistical analysis, that the left-right condyle asymmetry was found; some asymmetry has been reported in studies using tomography.<sup>48,49</sup> In this study, downward condylar

	Age	S-/ Left	S-/ Right	A-P Left	A–P Right	Lateral	D Left	D Right
Age (mos.)	_							
S–I Left	.002	—						
<i>S–I</i> Right	.075	.442***	_					
A-P Left	045	369***	276***					
A–P Right	.049	234**	219**	.298***	—			
Lateral	183*	.060	263**	.376***	299***	—		
D Left	048	.803***	.310***	068	320***	.227**	—	
D Right	.025	.385***	.743***	021	.015	072	.424***	—
ANB	.005	.150	014	.144	.136	.075	.192*	.057
SNMP	.213**	030	.042	063	.057	098	061	019

TABLE 4. Pearson's Correlation Coefficients

\* *S–I* indicates superioinferior component of condylar displacement; *A–P*, anteroposterior component of condylar displacement; and *D*, three-dimensional distance of condylar displacement. \*, *P* < .05; \*\*, *P* < .01; and \*\*\*, *P* < .001.

displacement was greater on the left side and forward condylar displacement was greater on the right, while threedimensional distance of condylar displacement was nearly identical for both sides. The right condyle axis tended to have an anterior component of displacement, while the left did not. These features of condylar displacement might swing the anterior part of the mandible toward the left side. In this study, only a weak, positive correlation (R = .298,P < .001) was found between the anteroposterior condylar movements bilaterally. Further, it has been reported that the relationship between condylar position asymmetry and the direction of dental midline discrepancy is not close.<sup>26,50</sup> Accordingly, the possible lateral swing caused by asymmetric condylar displacement of the mandible is, at best, a partial cause of facial asymmetry.<sup>51,52</sup> Only weak correlations in magnitude or direction of condylar displacement between the right and left sides were found in this study and others,<sup>29</sup> which might be related to the asymmetry of condylar positions.<sup>26,50,53</sup> Judging from correlations between L, A-P, and S-I, a condylar shift toward the left side would tend to bring the right condyle downward and forward and the left condyle backward.

In the majority of the patients, the condylar axis was directed downwards with an anteroposterior component, from CR position during the jaw closure to CO. This is in agreement with the displacement observed in previous studies.47,54 Such condylar displacement could be confirmed by the high correlation between the three-dimensional displacement and the downward displacement on the ipsilateral side. The downward movement could have been caused by rotation around a molar fulcrum into CO.18 When the condyle is directed downwards, dysfunctional conditions might occur; the space between the condyle and the eminence opens, the disc displaces,<sup>55</sup> stretch and denervation of the temporomandibular and collateral ligaments or muscle hyperactivity occurs.56 Our criteria for judging discrepancy might be significant<sup>29</sup> (ie,  $\geq 2 \text{ mm}$  in the sagittal plane or  $\geq 0.5$  mm in the transverse direction) because it has been indicated that a condylar displacement greater than 1 mm horizontally or vertically or 0.5 mm transversely may

have an adverse effect.<sup>19</sup> In this study, 31% (47/150) of the subjects had lateral shifts at the condylar level of 0.5 mm or greater, which is almost double the frequency (16%) reported previously.<sup>29</sup> On the other hand, in the superoinferior or anteroposterior direction, the frequency of significant discrepancy observed in the present study (16%, 24/150) was almost equal to that (19%) reported previously.29 Sixtyone percent of the patients of this study had no significant displacement in any of the spatial axes. The ratio (61%) was lower than that reported previously (81%), which seems to be due to the high incidence of significant lateral discrepancy in Japanese orthodontic patients. The high incidence of lateral displacement might be explained by a possible difference in anatomical characteristics of the temporomandibular joint structures, dental arch forms, or both. Further studies are needed to ascertain the true cause.

Lateral displacement was the most prevalent type of displacement (as shown in Table 2) and the most clinically critical type of displacement.<sup>25</sup> Even for the lateral displacement, however, significant differences were not found among the groups classified by age, gender, or Angle classification. The mean transverse CO-CR difference was 0.0 mm, which is smaller than that reported by Utt et  $al^{29}$  (0.27) mm), but the transverse difference in the present study had a much wider dispersion and range. The other noteworthy aspect was that only the Angle Class III group tended to have a transverse displacement toward the left side. The unique feature of the Class III group might partly be related to the findings that excessive mandibular growth often has been noted to be asymmetric and that Class III patients tended to have a higher frequency of asymmetry than other groups.57,58

#### CONCLUSIONS

The frequency, magnitude, or direction of CO-CR changes at the level of the condyles cannot be predicted by age, gender, Angle classification, ANB angle, or mandibular plane angle.

An asymmetric condylar displacement from CR to CO

was found in Japanese orthodontic patients. The downward displacement on the left side was greater (P = .02) than that on the right side, and the forward displacement on the right side was larger (P < .0001) than that on the left side. Significant condylar displacement was found most frequently in the lateral direction and Angle Class III patients tended to have significant displacement toward the left side. Fifty-eight patients (38.7%) had significant condylar displacement.

These results suggest that orthodontists should measure condylar displacement before the start of comprehensive orthodontic treatment to unmask a real jaw relationship and to avoid a possible misdiagnosis.

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