Original Paper

Comparison of the Arcon and the Condylar type articulators on the reproduction of lateral movements Part II: Applying the same articulator settings

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Abstract: There are two types of adjustable articulators, the Arcon and Condylar. The guiding systems are located on the upper member of the Arcon type articulator and on the lower of the Condylar type articulator. The movement of the articulators are different when the articulator settings on the adjustable mechanisms of both articulators are the same in the reproduction of lateral movements. In addition, when the movements of both articulators are the same, the articulator settings are different.

In the present study, we have focused on the effects of the guiding systems on the movement of the articulators. In order to evaluate the difference between type I and type VIII articulators (type I: which has the Arcon type guiding system on the upper member, type VIII: which has the Condylar type guiding system on the lower member), we calculated the lateral movements of both articulators by using a mathematical formulae.

The results are as follows:

When we apply the same articulator settings of the average lateral movement to both articulators, the largest difference takes place on the horizontal projective angle of the non-working side condylar guidance at 2.8°, whereas the smallest difference is observable on the sagittal projective angle of the non-working side condylar guidance at 0.6°. The three-dimensional discrepancies between both articulators are almost the same on the condylar and tooth pathways at about 0.15mm. This difference is explained by the three-dimensional rotation occurring during the lateral movement. Therefore, the difference between both articulators is affected by the articulator settings of the adjustable mechanisms.

I. Introduction

Several studies^{1~8)} comparing the Arcon and the Condylar type articulators dealing with the protrusive movement were done beginning with Bergström's work¹⁾ (1950). However, the aim in terms of using the adjustable articulator has to be focused on the reproduction of lateral movements. Although Weinberg⁵⁾ and Hasegawa et al⁹⁾ studied the reproducibility of articulators from a two-dimensional and horizontal approach, three-dimensional analysis has not yet been done. To overcome this, we have studied and theoretically classified articulators into eight groups under new criteria, depending on the guiding systems of the articulators¹⁰⁾.

In this study, mathematical analysis was employed to clarify the differences between the Arcon type articulator type I (all guiding systems are Arcon) and the Condylar type articulator type VIII (all guiding systems are Condylar) using the new criteria. The same articulator settings were applied to both articulators and the angular differences and the three-dimensional discrepancies between both articulators were calculated.

II. Methods

When we apply the same articulator settings of the lateral movement to type I (Arcon type) and type VIII (Condylar type), it is possible to calculate the lateral movements of both articulators by Hasegawa's mandibular movement cubic model¹¹⁾ as follows:

We defined the three-dimensional locations of the average articulator as coordinates.

Working side condyle	WC	(0, 0, 0)
Non-working side condyle	BC	(0, 110, 0)
Incisal point	I	(85, 55, -35)
Working side molar	MW	(40, 25, -35)
Non-working side molar	MB	(40, 85, -35)

The origin of the reference coordinate system is the center of the right condyle (working side condyle). The Y axis shows the intercondylar axis. The X-Y plane that parallels to the Camper's plane is used for the reference horizontal plane (Fig. 1).

Type I has exactly the same guiding system as the human jaw (all guiding systems and the horizontal reference plane are on the upper member of articulator), therefore we calculate the lateral movement of type I by moving from $\triangle WC, BC, I$ (intercuspal position) to $\triangle WC', BC', I'$ (lateral occlusal position). The guiding systems of type VIII are totally unlike

Fig.1 Calculation of the lateral movement on type I and VIII articulators.

WC : Working side condyle

BC : Non-working side condyle

I : Incisal point

$\triangle WC, BC, I$: Intercuspal position

$\triangle WC', BC', I'$: Lateral occlusal position of type I articulator

$\triangle WC'', BC'', I''$: Lateral occlusal position of type VIII articulator

the human jaw (all guiding systems and the horizontal reference plane are on the lower member of articulator). The upper member of type VIII is moved along the guiding mechanism of the lower member. To compare the lateral movements of both articulators, it is necessary to calculate the lateral movement of type VIII for the upper member (the horizontal reference plane of type I). The articulator setting angles of type VIII are equal to the articulator setting angles of type I with 180° added. When we apply the same articulator settings to both articulators, the lines $BC-BC'$ and $WC-WC'$ are shown as the condylar pathways of type I and the lines $BC-BC''$ and $WC-WC''$ are shown as type VIII. The traversed distance of the non-working side condyle $BC-BC'$ (type I) is equal to $BC-BC''$ (type VIII). By calculating the intercuspal position of type VIII ($\triangle WC, BC, I$) relative to the lateral occlusal position ($\triangle WC'', BC'', I''$), we can calculate the lateral movement of type VIII for the upper member of articulator (Fig. 1).

The articulator settings we used for type I and VIII are as follows:

Traversed distance of non-working side condyle

$a : 4\text{mm}$

Sagittal projective angle of non-working side condylar guidance $\theta : 20^\circ, 40^\circ, 60^\circ$

Horizontal projective angle of non-working side condylar guidance $\alpha : 5^\circ, 10^\circ, 20^\circ, 30^\circ$

Horizontal projective angle of working side condylar guidance $\beta : -30^\circ \sim 30^\circ$

Frontal projective angle of working side condylar guidance $\gamma : -30^\circ \sim 30^\circ$

Sagittal projective angle of incisal guidance

$\phi : 0^\circ, 20^\circ, 40^\circ, 60^\circ, 80^\circ$

The distance traversed by the non-working side condyle (4mm) was decided on the basis of the occlusal contact between the upper and lower molars during the lateral movement. The working-side guidance (-) indicates forward and downward directions.

Lateral movements of the articulators were calculated. The differences of movement were then quantified at the joints and at the incisal and molar regions. The differences were evaluated as angular differences of direction of the two articulator pathways. The three-dimensional discrepancies were shown as a three-dimensional distance of the end-points between two articulator pathways.

III. Results

By applying the average lateral movement^{12,13)}, such as $\phi=60^\circ$ for the sagittal projective angle of the incisal guidance, $\theta=40^\circ$ for the sagittal projective angle of the non-working side condylar guidance, $\alpha=10^\circ$ for the horizontal projective angle of the non-working side condylar guidance, $\beta=0^\circ$ for the horizontal projective angle of the working side condylar guidance and $\gamma=0^\circ$ for the frontal projective angle of the working side condylar guidance to type I (all guiding systems are the Arcon type) and to type VIII (all guiding systems are the Condylar type), the resultant angles were quantified in both articulators (Table 1). The articulator setting angles of type VIII show the values calculated for the upper member (the horizontal reference plane of type I). The difference in the sagittal projective angle of the non-working side condylar guidance showed the lowest value at 0.6° and the difference in the horizontal projective angle of the non-working side condylar guidance showed the highest value at 2.8° . Three-

Table 1 Differences of the articulator settings between type I (Arcon type) and type VIII (Condylar type) articulators on the average lateral movement.

Condylar and incisal guidance	type I	type VIII
Sagittal projective angle of non-working side condylar guidance (θ)	40°	40.6°
Horizontal projective angle of non-working side condylar guidance (α)	10°	12.8°
Horizontal projective angle of working side condylar guidance (β)	0°	1.6°
Frontal projective angle of working side condylar guidance (γ)	0°	1.3°
Sagittal projective angle of incisal guidance (ϕ)	60°	61.7°

Table 2 Three-dimensional discrepancies of the condylar and tooth pathways between type I and VIII articulators on the average lateral movement.

Condylar and tooth pathway	Discrepancy (mm)
Non working side condyle	0.149
Working side condyle	0.144
Incisal point	0.151
Non-working side molar	0.157
Working side molar	0.150

dimensional discrepancies of the condylar and tooth pathways between both articulators were almost the same (0.15mm) (Table 2).

Furthermore, the influences of changing the articulator settings were calculated. Fig. 2 shows the three-dimensional discrepancies of condylar and tooth pathways when the sagittal projective angle of the incisal guidance (ϕ) was changed from 0° to 80° . Fig. 3 shows the three-dimensional discrepancies of condylar and tooth pathways when the sagittal projective angle of the non-working side condylar guidance (θ) was changed from 20° to 60° . When the sagittal inclination of the incisal guidance shows the same value as the sagittal inclination of the non-working side condylar guidance, the discrepancies between type I and VIII in the condylar

Fig. 2 Three-dimensional discrepancies of the condylar and tooth pathways between type I and VIII articulators, when the sagittal projective angle of the incisal guidance (ϕ) was changed from 0° to 80° .

I : Incisal point
 BM : Non-working side molar
 WM : Working side molar
 BC : Non-working side condyle
 WC : Working side condyle

Fig. 3 Three-dimensional discrepancies of the condylar and tooth pathways between type I and VIII articulators, when the sagittal projective angle of the non-working side condylar guidance (θ) was changed from 20° to 60° .

and tooth pathways are the same (0.14mm). In this case, the calculated sagittal projective angle of the incisal guidance (ϕ) and non-working side condylar guidance (θ) had the same values for the applied sagittal projective angles, which

Fig. 4 Three-dimensional discrepancies of the condylar and tooth pathways between type I and VIII articulators, when the horizontal projective angle of the non-working side condylar guidance (α) was changed from 5° to 30° .

Fig. 5 Three-dimensional discrepancies of the condylar and tooth pathways between type I and VIII articulators, when the horizontal projective angle (β) and the frontal projective angle (γ) of the working side condylar guidance were changed from -30° to 30° .

The discrepancies in both articulators were shown as a distance from the origin of the coordinate axis according to the direction of the working side condylar sagittal projective angle. The circles in figure show the values of discrepancies when applying the average lateral movement.

indicates a sagittal rotational movement did not take place during this lateral movement. Greater differences between the sagittal condylar inclination and the sagittal incisal inclination occurred when larger discrepancies were raised between the

articulators. This tendency was also noticeable on the tooth pathways.

There were few effects on the discrepancies between both articulators when the horizontal projective angle of the non-working side condylar guidance (α) was changed from 5° to 30° . This indicates that the changing of the horizontal projective angle of the non-working side condylar guidance did not affect the horizontal rotational movement during the lateral movement (Fig. 4).

Fig. 5 shows the three-dimensional discrepancies of condylar and tooth pathways when the horizontal projective angle (β) and the frontal projective angle (γ) of the working side condylar guidance were changed from -30° to 30° . The discrepancies of both articulators are shown as the distance from the origin of the coordinate axis according to the direction of the working side condylar sagittal projective angle, for example, the working side condylar pathway $\beta = -30^\circ$, $\gamma = 30^\circ$ shows a direction of 45° in the first quadrant and $\beta = -30^\circ$, $\gamma = 0^\circ$ indicates the anterior direction of the coordinate axis. The circles in the figure show the values of the discrepancies when applying the average lateral movement. The discrepancies between both articulators are affected by changing the direction of the working side condylar guidance.

IV. Discussion

Articulators are classified as the Arcon type when the guiding systems are on the upper member and as the Condylar type when they are on the lower member. The relationship between the condylar setting angles of the Arcon type and the horizontal reference plane, (the upper member of the articulator) does not change when the upper member is moved, because the horizontal reference plane and condylar guidance are moved at the same time. When the upper member of the Condylar type is moved, the angles of the condylar guidance are changed sequentially according to the movement. Although, when the sagittal inclination of the condylar and incisal guidance on the protrusive movement are the same, the movement of the Arcon and Condylar type is the same. When the sagittal inclination between the condylar and incisal guidance are different, differences of the protrusive movement between both articulators occur. This creates a rotational movement in the sagittal plane. The three-dimensional rotation is raised on the articulators in the reproduction of lateral movements. When the same movement is reproduced on both articulators, the setting angles of the

adjustable mechanisms are often different, furthermore the movements of the articulators are different when the same articulator settings are applied.

Weinberg⁵⁾ and Hasegawa et al⁹⁾ have also investigated the horizontal differences between both articulators. Weinberg⁵⁾ calculated the difference on the Bennett angle (the horizontal projective angles of the non-working side condylar guidance). Hasegawa et al⁹⁾ investigated the differences on the non-working side, working side condylar pathways and tooth pathways when changing the horizontal projective angles of the non-working and working side condylar guidance. However, three-dimensional analysis has not yet been done.

In this study, we analyzed the difference between the Arcon and Condylar type geometrically during the lateral movement by using a three-dimensional model. We selected type I which has the same mechanics as the human jaw and type VIII which is totally dissimilar and applied the same articulator settings to both, to clarify where the Arcon type and the Condylar type are different.

By applying the average lateral movement to both articulators, the difference in the sagittal projective angle of the non-working side condylar guidance was the lowest and the difference in the horizontal projective angle of the non-working side condylar guidance was the highest. This result from the lateral movement is chiefly driven by the horizontal rotational movement with the center rotation point on the working side condyle. The discrepancies in pathways between them were almost the same on the working and non-working condylar pathways, incisal, non-working molar and working molar pathways at about 0.15mm. The discrepancies between both articulators are affected by changing the articulator settings. This is due to the three-dimensional rotational change of the upper member of type VIII. For this reason, the larger discrepancies between both articulators are raised when the larger differences of the sagittal projective angles between the non-working side condylar guidance and the incisal guidance take place and when the direction of the working side condylar guidance differs significantly from the direction of the non-working condylar guidance.

As mentioned above, when applying the average lateral movement to type I and VIII, the differences between both articulators are clearly shown on the horizontal projective angle of the non-working side condylar guidance (Bennett angle). The three-dimensional discrepancy between both articulators was almost constant (0.15mm). These differences

were created by three-dimensional rotation during the lateral movement, they were affected by the articulator settings of the adjustable mechanisms.

With the Denar pantronic system¹⁴⁾ and the Panadent quick analyzer system¹⁵⁾, the transferring procedures of the lateral movement to the articulators are omitted. The values of the condylar pathways measured by these systems are applied directly to the adjustable mechanism of the articulator. In the future, the mandibular movement will be easily and precisely measured using the six degrees of freedom jaw movement tracking device. In transferring the mandibular movement to the articulator, the measured values of the condylar pathways will be set on the adjustable mechanism of the articulator. In this case, the Arcon type should be used. The discrepancies occur on the condylar and tooth pathways when using the Condylar type. This value is about 0.15mm with the application of the average lateral movement.

V. Conclusion

In order to evaluate the different movements between the Arcon type guiding system and the Condylar system mathematically, we applied the same articulator settings for the lateral movement to type I articulator, which has the Arcon type guiding system on all adjustable mechanisms, and type I articulator, which has the Condylar type guiding system on all adjustable mechanisms.

The results are as follows:

1. The movement of type VIII articulator differs from type I articulator when applying the same settings for the lateral movement.
2. The differences between both articulators are obvious on the horizontal projective angle of the non-working side condylar guidance (Bennett angle).
3. The three-dimensional discrepancies between both articulators in the condylar and tooth pathways are approximately 0.15mm with the application of the average lateral movement and are affected by the setting angles of the adjustable mechanisms of the articulators.

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