

Original Article

Effect of a novel rotation coordinating device on registered horizontal condylar guidance of nonarcon semi-adjustable articulators

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ABSTRACT

Background: Horizontal condylar guidance (HCG) is registered by protrusive interocclusal records but in nonarcon articulators, these records can affect the accuracy. The present study aimed to evaluate the effect of a novel rotation coordinating device (RCD) on condylar guidance setting with protrusive interocclusal records.

Materials and Methods: The study was designed as a comparative *in-vitro* investigation. Stone maxillary and mandibular casts were mounted on a fully adjustable instrument as the patient. Duplicate casts were mounted on an arcon and a nonarcon articulator with corresponding face bow records and in maximum intercuspation relation. Five different condylar guidance inclinations for both sides (20°, 30°, 40°, 50°, and 60°) were set on the fully adjustable instrument and 16 protrusive interocclusal records were established at each setting. HCG was set for arcon, nonarcon articulators, and nonarcon articulators with RCD. Data were analyzed using one-sample *t*-test to compare with actual HCG and one-way analysis of variance ($\alpha = 0.05$).

Results: Mean HCG for studied articulators was 35.40 for arcon, 30.31 for nonarcon without RCD, and 35.61 for nonarcon with RCD which were significantly different from actual HCG ($P < 0.05$). HCG of the nonarcon with RCD showed no significant difference with arcon articulator ($P = 0.71$) while both were significantly different from nonarcon without RCD ($P < 0.001$).

Conclusion: "The RCD" compensates the condylar guidance inclination difference between arcon and nonarcon articulators. The device precisely transfers the hinge movement of the upper member of the articulator to the condylar track.

Key Words: Articulator, mandibular condyle jaw relation records, occlusal adjustment

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INTRODUCTION

The occlusal surface of restoration should allow opposing teeth to pass each other in harmony with mandibular movements and their determinants.^[1] Horizontal condylar guidance (HCG) is the posterior determinant of eccentric jaw movements.^[2] Steep

HCG allows more cuspal inclination. Flatter teeth are in harmony with less steep HCG.^[1]

Two major types of articulators have been introduced to mimic temporomandibular joints and jaw

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movements: arcon and nonarcon. The angle between the occlusal plane and condylar track changes during the hinge movement of the upper member of nonarcon articulators while in the case of arcon articulators, this angle would not be affected.^[3]

When the HCG of the nonarcon articulator is adjusted using an extrusive interocclusal record, closing movement after removing the interocclusal record results in a less steep angle between the upper member and the condylar track (flatter HCG). Less steep HCG produces teeth with less cusp height, fossa depth, and cusp inclines to prevent occlusal interferences.^[1-3] This is an acceptable compromise but not an ideal outcome. Because changes produce flat teeth which may prevent posterior occlusal interferences in extrusion but also reduce masticatory efficacy.^[1]

Comparative studies on the accuracy of arcon and nonarcon articulators have yielded controversial results. There are controversies regarding the difference and accuracy of arcon and nonarcon articulators. Condylar guidance angles obtained using arcon articulators are relatively similar to nonarcon instruments in some studies,^[4-6] and also significantly different in other studies.^[7,8]

The “rotation coordinating device” (RCD) is supplementary for nonarcon articulators to maintain the correct HCG during hinge movements.^[9] The device provides a tight connection of the articulator condylar axis to the condylar track to transmit rotations of the articulator condylar axis to the condylar track. Hence, components rotate coordinated by the same degree and direction^[9] [Figure 1].

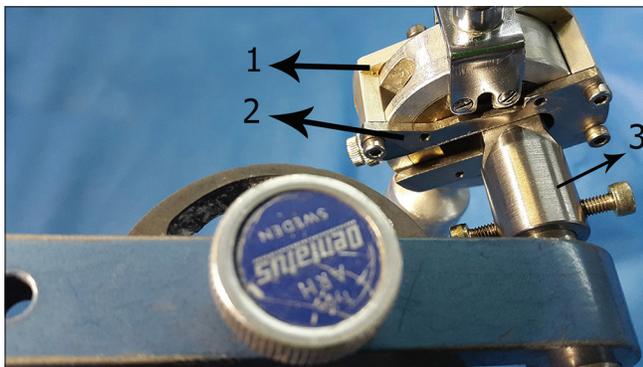


Figure 1: Rotation coordinating device consists of components that tightly engage with condylar axis and condylar track of articulator to provide a mechanical connection of these parts. 1 and 2: Components that engage condylar track. 3: Component that engages condylar axis.

The study aimed to evaluate the effect of the RCD on the accuracy of HCG adjustment in nonarcon articulators. The null hypothesis is that there is no difference between the registration of HCG with and without RCD in nonarcon articulators.

MATERIALS AND METHODS

The study was designed as a comparative *in-vitro* investigation a fully adjustable articulator served as hypothetical patients. Irreversible hydrocolloid (Alginoplast Alginate; Heraeus Kulzer GmbH) was used to obtain impressions from the maxillary and mandibular dental arch of a volunteer with an intact masticatory system. Stone casts were duplicated three times using additional silicone (Silatec, DMG) molds to fabricate three pairs of stone casts. One pair was mounted on the fully adjustable articulator (Artex-Reference, Amann Girbach Dental GmbH) in an average arbitrary position in the maximum intercuspation. Face bow registrations were done to mount the remaining pairs of casts on two semi-adjustable articulators (Artex CPR [Amann Girbach] as arcon articulator and Dentatus ARH [Dentatus AB]) as nonarcon articulator. For face bow registration, condylar rods of the face bow were exactly positioned on the hinge axis of the fully adjustable articulator (hypothetical patient’s hinge axis). A small round hole was made on the lateral surface of the maxillary cast as the third point of reference. The vertical distance between the hole and the center of the hinge axis of the articulators was measured by a height gauge with 0.02 mm accuracy (Mitutoyo 506-208 Vernier Height Gauge, Mitutoyo) and used for positioning the casts in the semi-adjustable articulators.

Protrusive interocclusal records were obtained from the hypothetical patients.

HCG of the fully adjustable articulator was set on five different angles for both sides (20°, 30°, 40°, 50°, and 60°). Sixteen serial protrusive records were obtained using additional silicon bite registration material (Futar D, Kettenbach GmbH) in each HCG (80 protrusive records). The sample size was calculated statistically which showed that 16 measurements per group were needed ($\alpha = 0.05$ and Power = 0.80, $d = d = 3.4$). All records were obtained in the same eccentric position (edge-to-edge position) by an anterior auto-polymerizing resin jig (DuraLay Inlay Pattern Resin, Reliance Dental Manufacturing).

Each protrusive record was used to adjust the HCG of arcon and nonarcon articulators. The angle between

the longitudinal axis of the upper member and the condylar path of the articulators was measured as HCG using the method described by “Manshaee and Shakerin.”^[9] Using the same manner, the hinge movement of the upper member and rotation of the condylar tracks also were determined by measuring the difference between their orientations before and after record removal^[9] [Figure 2].

HCG of fully adjustable articulators for each of the five fully adjustable articulator settings was determined by a single measurement. HCG of nonarcon articulator before record removal (NARC-R) was measured first, then RCD was mounted on the articulator and after removing the record HCG of nonarcon articulator with the RCD (NARC-RCD) was measured. HCG of nonarcon articulator after record removal without the RCD (NARC-NR) was also recorded [Figure 2]. The rotation of the upper member of nonarcon articulator after removal of the records and rotation of its condylar path when using RCD were also recorded.^[9]

The mean HCG of each studied group was compared with the HCG of hypothetical patients with one-sample *t*-test. One-way analysis of variance and Duncan *post hoc* tests were used to find the differences in HCG between studied groups. Pearson’s correlation coefficient was used to find the relation between the rotation of the upper member of the nonarcon articulator after the removal of the records and the rotation of the condylar path with RCD (SPSS version 22.0; SPSS Inc. IBM company, Armonk, New York, U.S.) ($\alpha = 0.05$ and $\beta = 0.2$ for all tests).

RESULTS

Table 1 shows that the mean HCG of all semi-adjustable articulators was different from actual HCG of arcon articulator (ARC), nonarcon articulator after record removal without using RCD (NARC-NR) and nonarcon articulator after record removal by using RCD (NARC-RCD) in 20.17° test value. One-way analysis of the variance of studied groups showed that there are significant differences between the registered HCG of studied groups [Table 2]. The registered HCG of nonarcon articulator after removing the interocclusal records was significantly less than all studied groups [Table 1 and Figure 3].

The mean rotation movement of the nonarcon articulator upper member ($5.26^\circ \pm 0.68^\circ$) was significantly correlated to the rotation of the right ($5.54^\circ \pm 0.84^\circ$) and left ($5.41^\circ \pm 1.01^\circ$) condylar tracks (right: $r = 0.60$,

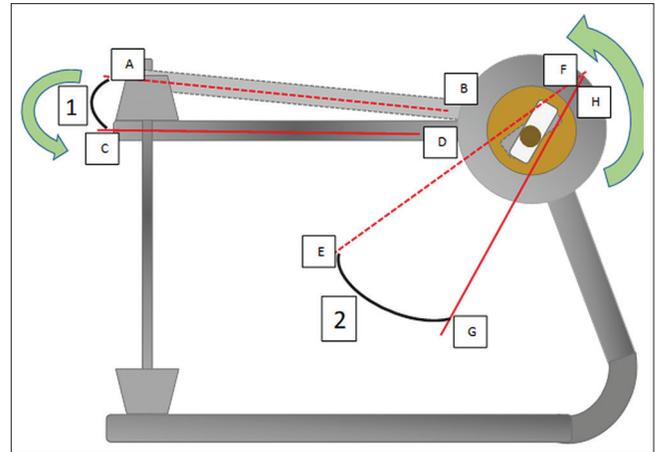


Figure 2: Horizontal condylar guidance and hinge movements in nonarcon articulator. AB and CD line: Plane of upper member before and after record removal, respectively. E and F: Orientation of condylar track before record removal and after record removal without using rotation coordinating device (RCD). G and H: Orientation of condylar track after record removal by using RCD. 1: The angle between AB line and CD line represents the hinge movement of upper member. 2: The angle between EF and GH represents the rotation of condylar track. The angle between AB and EF was measured as horizontal condylar guidance (HCG) of nonarcon articulator before record removal (NARC-R). The angle between CD and EF was measured as HCG of nonarcon articulator after record removal without using RCD (NARC-NR). The angle between CD and GH was measured as HCG of nonarcon articulator after record removal by using RCD (NARC-RCD).

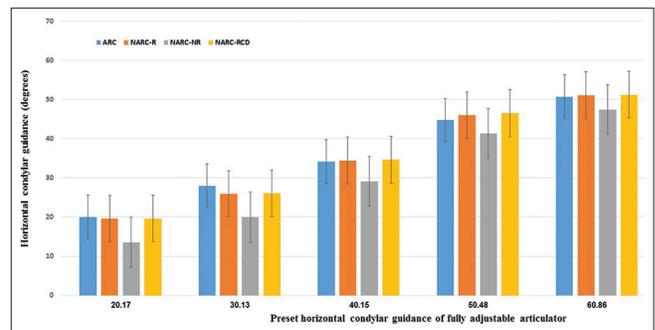


Figure 3: Horizontal condylar guidance of studied groups. ARC: Arcon, NARC-R: Nonarcon before record removal, NARC-NR: Nonarcon after record removal without using RCD, NARC-RCD: Nonarcon after record removal by using RCD.

$P < 0.001$, left: $r = 0.62$, $P < 0.001$) when RCD was used [Figure 4]. The correlation between the rotation movement of the upper member of the nonarcon articulator after removal of the record and the difference of registered HCG in ARC and NARC-NR groups were statistically significant ($r = 0.449$, $P < 0.001$). There was no statistically significant correlation between this rotation movement and the HCG difference of ARC and NARC-RCD groups ($r = 0.099$, $P = 0.386$) [Figure 5].

Table 1: One sample t-test was used for comparing the mean horizontal condylar guidance of studied groups and fully adjustable articulator values (°)

	Test value 1	Test value 2	Test value 3	Test value 4	Test value 5	Mean
Test value*	20.17	30.13	40.15	50.48	60.86	40.35
ARC						
Mean±SD	20.02±2.66 ^A	27.99±1.92 ^A	34.21±3.41 ^A	44.79±3.59 ^A	50.79±2.38 ^A	35.70±4.30
t	-0.22	4.77	-6.94	-6.34	-16.90	9.5
P	0.83	<0.001	<0.001	<0.001	<0.001	<0.001
NARC-R						
Mean±SD	19.62±2.74 ^A	25.96±3.00 ^A	34.48±2.93 ^A	46.07±3.63 ^A	51.16±4.25 ^A	35.6±3.90
t	-0.77	5.92	-7.73	-4.85	-9.14	10.4
P	0.45	<0.001	<0.001	<0.001	<0.001	<0.001
NARC-NR						
Mean±SD	13.54±2.36 ^B	19.99±2.83 ^B	29.15±3.72 ^B	41.38±3.89 ^B	47.52±3.57 ^B	30.30±3.80
t	-11.25	-14.33	-11.83	-9.35	-14.96	22.9
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NARC-RCD						
Mean±SD	19.67±2.90 ^A	26.03±3.07 ^A	34.68±3.05 ^A	46.56±3.67 ^A	51.30±4.22 ^A	35.80±4.00
t	-0.67	5.96	-7.16	-4.26	-9.06	9.9
P	0.51	<0.001	<0.001	0.001	<0.001	<0.001

*Test values are the exact HCG which measured in the fully adjustable articulator. Identical superscript uppercase letters show no significant difference between studied groups (Duncan *post hoc* test: $P=0.70$ for 20.17°, $P=0.051$ for 30.13°, $P=0.71$ for 40.15°, $P=0.21$ for 50.48°, and $P=0.71$ for 60.86°). ARC: Arcon; NARC-R: Nonarcon with interocclusal record; NARC-NR: Non-ARC without interocclusal record; NARC-RCD: Non-ARC with rotation coordinating device; HCG: Horizontal condylar guidance; SD: Standard deviation

Table 2: One-way analysis of variance ($\alpha=0.05$) of studied groups in different horizontal condylar guidance (°)

Studied HCG*	Comparison	Sum of squares	df	Mean square	F	Significance
20.17	Between groups	463.915	3	154.638	21.747	0.000
	Within groups	412.417	58	7.111		
	Total	876.332	61			
30.13	Between groups	576.557	3	192.186	25.518	0.000
	Within groups	451.876	60	7.531		
	Total	1028.433	63			
40.15	Between groups	339.725	3	113.242	10.419	0.000
	Within groups	652.109	60	10.868		
	Total	991.834	63			
50.48	Between groups	262.078	3	87.359	6.383	0.001
	Within groups	821.179	60	13.686		
	Total	1083.257	63			
60.86	Between groups	155.014	3	51.671	3.809	0.014
	Within groups	813.891	60	13.565		
	Total	968.905	63			

*HCG: Horizontal condylar guidance

DISCUSSION

The null hypothesis was rejected because the HCG without RCD was significantly different from other groups [Table 1]. Christensen^[10] proposed adjusting HCG using protrusive interocclusal records. The interocclusal record method is simple and practical for HCG adjustment directly on the articulator with no sophisticated equipment. However, the HCG of the nonarcon articulator would change after the interocclusal record is removed from the articulator.^[3]

Manshaee and Shakerin^[9] introduced a novel RCD to maintain the correct HCG of nonarcon articulators. The current study was conducted to evaluate the effect of this device on the accuracy of the HCG setting.

In clinical studies, pantographic values^[5,11-15] or radiographic inclination of articular eminence^[7,16,17] have been compared with the HCG of articulators. In this study, a fully adjustable articulator was used to simulate patients according to previous studies.^[18] Hence, the measured HCG of the fully adjustable

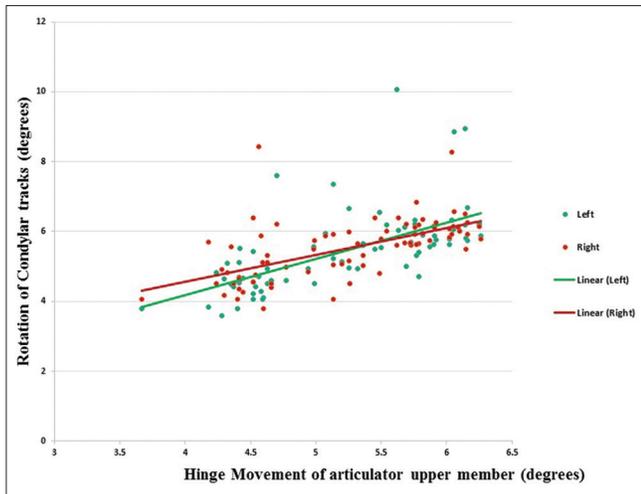


Figure 4: Correlation between rotation movement of upper member of nonarcon articulator and rotation coordinating device-mediated rotation of condylar tracks (right: $R = 0.60$, $P < 0.001$, left: $R = 0.62$, $P < 0.001$).

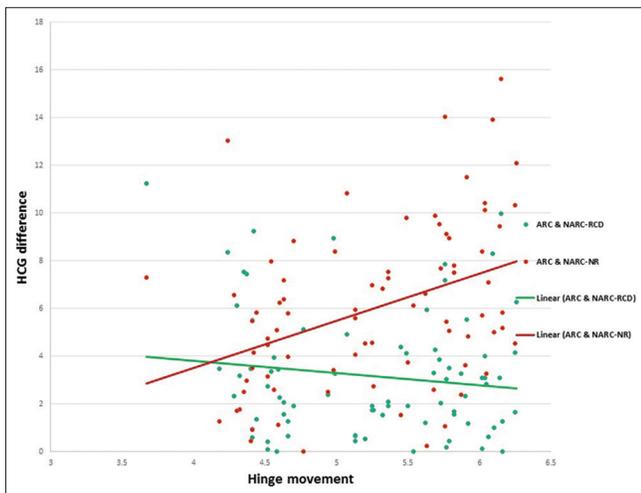


Figure 5: Correlation between rotation movement of upper member of nonarcon articulator and difference of horizontal condylar guidance of arcon and nonarcon articulator groups ($r = 0.449$, $P < 0.001$) ($r = 0.099$, $P = 0.386$). ARC: Arcon, NARC-NR: Nonarcon after record removal without using RCD, NARC-RCD: Nonarcon after record removal by using RCD.

articulator was the actual posterior determinant of movements. In addition, confounding factors were eliminated and there was no concern about the patient's neuromuscular control that can interfere with jaw movement.^[19] Additional silicone was used as check bite material due to high accuracy and dimensional stability.^[20-22] Accuracy of HCG adjustment would be affected by the degree of protrusion.^[6,23] To provide identical protrusion, the same anterior jig was used to make records in edge-to-edge teeth position for all the specimens.

HCG of the arcon articulator was significantly flatter than the actual HCG ($4.6^\circ \pm 4.3^\circ$ on average, $P < 0.001$). There was also a significant difference ($4.7^\circ \pm 3.9^\circ$ in average, $P < 0.001$) between the actual HCG and conventional nonarcon instrument before record removal which reached $10.0^\circ \pm 3.8^\circ$ when the record was removed [Table 1]. This is in agreement with previous studies that imply HCG adjustment (in both arcon and nonarcon articulators) through interocclusal records tends to result in flatter inclination in comparison with patient-attributed HCG obtained from radiographs or pantographic tracings. However, some differences were found in results regarding HCG test values: mean HCG of ARC, NARC-NR, and NARC-RCD groups were similar to actual HCG values in the 20.17° test value. In steeper HCG, the differences between fully adjustable values and other groups were increased. This may be related to thicker elastomeric interocclusal records in steeper HCG that result in more compressibility of the record under hand pressure which produces flatter HCG. In contrast, Gross *et al.*^[13] found 4° – 17.8° higher HCG of 3 arcon instruments than pantograph records. The extreme length of the pantographic protrusive path (8 mm) may be the reason for Gross *et al.* results.^[13] Hence, both arcon and nonarcon instruments are prone to exert significant errors although errors are higher in nonarcon articulators. Overlooked record-cast maladaptation, record compression due to the force applied on the articulator, and sensitivity of HCG components of the articulator may be reasons for repeated flatter HCG in instruments.^[6,13,23]

No significant difference was detected between the arcon and nonarcon instruments before record removal [Table 1]. HCG of the nonarcon instrument was reduced significantly after record removal ($5.2^\circ \pm 0.7^\circ$ in average) which was also significantly lower than the HCG of the arcon articulator ($5.2^\circ \pm 4.2^\circ$, $P < 0.05$). The findings of the current study about the difference in HCG between arcon and nonarcon instruments are in accordance with Zabarović *et al.*^[8] and Shillingburg and Sather^[24] but are not in concurrence with other previous studies.^[5-7,25] Shillingburg and Sather^[24] state that the HCG of the nonarcon articulator is reduced by 8° after record removal. Other authors have not found significant statistical differences between the two types of instruments.^[5,6,25] In the current study, the upper member of the nonarcon articulator rotates by $5.2^\circ \pm 0.6^\circ$ that is significantly correlated with the mean

HCG difference found between ARC and NARC-NR groups ($r = 0.449$, $P < 0.001$) [Figure 5]. Hinge movement is the source of the HCG difference between arcon and nonarcon articulators and the controversial results of studies may be due to a different amount of hinge movement.

The result of the current study showed that the use of RCD can significantly increase the HCG of nonarcon articulators in comparison with NARC-NR ($5.4^\circ \pm 0.8^\circ$, $P < 0.05$). The recorded HCG with RCD (NARC-RCD) was not significantly different from the ARC group [Table 1]. Furthermore, using the RCD, the difference between ARC and NARC-RCD was not affected by rotation the of articulator upper member ($r = 0.099$, $P = 0.386$) [Figure 4].

Previous studies found that even 5° alteration of HCG has a certain effect on cusp height and steepness that may lead to occlusal errors.^[26-28] However, according to the current study, the possibility of protrusive and nonworking occlusal interferences might be reduced because regardless of articulator type, registered HCG was lower than actual HCG. On the other hand, using arcon and nonarcon articulators with RCD greater HCG was registered than nonarcon articulator without RCD resulting in steeper occlusal inclinations that can lead to improved masticatory function, however, conventional nonarcon articulators should not be considered invalid instruments because the functional significance of flatter occlusal surface due to reduced HCG following record removal is not documented.

One of the limitations of the current study is that hand pressure was used for seating the cast on the protrusive record during HCG adjustment and this may vary between adjustments which can cause some inaccuracies. Standardized method for applying a fix amount of pressure is proposed for future studies. The current study was performed in the relatively same hinge movement of mandible for all specimens. The RCD effectiveness may be different when the degree of rotation changes. Relatively controlled conditions of the current study may yield optimistic results for HCG of arcon and RCD-modified nonarcon articulators comparing with actual values. Results may vary in clinical situations.

CONCLUSION

Within the limitation of this study, the following conclusions can be drawn regarding HCG registered by protrusive interocclusal records:

1. HCG of both arcon and nonarcon is significantly flatter than the patient's actual condylar guidance
2. After removal of interocclusal record, the HCG of the conventional nonarcon articulator is significantly less than arcon instrument
3. The RCD compensates the condylar guidance inclination difference between arcon and nonarcon articulator.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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