

A Comparison between the Horizontal Condylar and Bennett Angles of Iraqi Full Mouth Rehabilitation Patients by Using Two Different Articulator Systems (An *In-Vivo* Study)

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ABSTRACT

Background: Errors of horizontal condylar inclinations and Bennett angles had largely affected the articulation of teeth and the pathways of cusps. The aim of this study was to estimate and compare between the horizontal condylar (protrusive) angles and Bennett angles of full mouth rehabilitation patients using two different articulator systems.

Materials and Methods: Protrusive angles and Bennett angles of 50 adult males and females Iraqi TMD-free full mouth rehabilitation patients were estimated by using two different articulator systems. Arbitrary hinge axis location followed by protrusive angles and Bennett angles, estimation was done by a semiadjustable articulator system. A fully adjustable articulator system was utilized to locate the terminal hinge axis using a kinematic face bow followed by protrusive angles location by the aid of two square shaped transparent hard plastic protractors attached close to the condylar stylus of the articulator followed by Bennett angles calculation according to the Hanau formula. All results were subjected to statistical analyses.

Results: The two articulator systems scored protrusive angles for male patients greater than female patients which were non-significant for the fully adjustable articulator but they were significant for the semiadjustable articulator. Non-significance existed between females of the fully adjustable articulator and males of the semiadjustable articulator while high significance was located between males of the fully adjustable articulator and females of the semiadjustable articulator. Concerning Bennett angles, the highest mean value belonged to the male group of the fully adjustable articulator, while the lowest scored by the female group of the semiadjustable articulator. Highly significant differences were located between the Bennett angle mean values of the groups.

Conclusion: Using both articulators, the total mean values of the males were greater than the females regarding both horizontal condylar angles and Bennett angles with the total means scored by the fully adjustable articulator being larger than those of the semi-adjustable type. Using both articulators, the males' right and left condyles exhibited greater Bennett angles than their female equivalents. The precision estimation of the horizontal condylar angles and Bennett angles provided by the condylar axis protractors of the fully adjustable articulator render such type of articulators most suitable for treating full mouth rehabilitation cases.

Keywords: Horizontal condylar angles, Bennett angles, two articulator systems. (J Bagh Coll Dentistry 2016; 28(1):26-35).

INTRODUCTION

The management of tooth wear, especially attrition, is becoming a subject of increasing interest in the prosthodontic literature, both from preventive and restorative points of view ⁽¹⁾. Focusing on the interactions between occlusion and brain function has been reported as brain activity may change depending on the strength of the movements in the oral and maxillofacial area. Therefore, mastication and other movements stimulate the activity in the cerebral cortex and may be helpful in preventing degradation of a brain function ⁽²⁾.

The relationship between the dental occlusion and temporomandibular disorders (TMDs) has been one of the most controversial topics in the dental community ⁽³⁾.

Oral rehabilitation restores form and function and impacts on general health. Teeth provide a discriminating sense of touch and directional specificity for occlusal perception, management of food with mastication and swallowing, and awareness of its texture and hardness.

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It has been shown that optimum restoration design appears to be significant for bone remodeling and bone strains around implants with occlusal loading. Load concentration increased with steeper cusp inclination and broader occlusal table and decreased with central fossa loading and narrower occlusal table size ⁽⁴⁾.

The primary objective of rehabilitating occlusion is to improve stomatognathic function in patients experiencing dysfunction in mastication, speech, and swallowing as a consequence of tooth loss. The procedure of occlusal treatment involves improving the morphology and the stomatognathic function ⁽⁵⁾.

Mastering occlusion is the primary objective that must be achieved in order to restore the function of the dentition to last a lifetime ⁽⁶⁾. The most difficult and potentially threatening oral rehabilitation involves all of the teeth on one or both arches being prepared at the same time, or when the vertical dimension of occlusion being changed. Diagnostic casts are a necessary aid in determining the characteristics of occlusion to be developed in the rehabilitated dentition. The pre-operative occlusion must be observed carefully on

diagnostic casts. If most of the characteristics of the original occlusion are replaced in the rehabilitated occlusion, the treatment will seldom, if ever, fail. On the contrary, if steep incisal guidance is placed in the mouth of a person who previously had worn his or her teeth into a group function, failure may occur over a short time. If a dentition is restored into a centric relation occlusion, when the natural occlusion had a long shift from centric relation to centric occlusion, broken porcelain on anterior maxillary crowns or drifting anterior teeth within weeks or months of seating the rehabilitation have been observed⁽⁷⁾.

On April 27th, 1908 Dr. Norman G. Bennett of London, England presented a paper on mandibular movements to the "Royal Society of Medicine Odontology Section"; the article, originally published in the proceedings of the society that year, reprinted in the Journal of Prosthetic Dentistry⁽⁸⁾. Specifically, he intended to show that no single fixed rotation center of the condyles exists, but that the center is constantly moving. That is, for any normal opening movement of the mandible, a succession of instantaneous centers of rotation occurs in a curved path.

These paths vary among individuals. He attached small light bulbs to a mandibular framework, one over the condyle and another at the symphysis and used lenses to focus the images on the wall, where they were traced during mandibular motion onto a sheet of paper placed in the sagittal plane, and the focused spots were marked by Bennett's brother at several intervals. Bennett's conclusions were that there was an instantaneous center of rotation that varied with different condylar movements and position, rather than a solitary, fixed center of rotation. Bennett made a secondary observation when spots were recorded in the frontal plane. He noticed a lateral shift in the position of the working condyle towards the side to which the movement was being made. In summary, he noted that when the mandible was moved bodily to one side, the condyle on the side of the movement rotated in place or moved slightly, and the opposite condyle (the side away from the movement) moved downward and forward. Bennett's report was considered important to bring to the attention of the profession a concept that "Balkwill" had discovered but had been neglected for over 40 years⁽⁹⁾.

The Bennett path influences the positions of the cusps in their mesiodistal relation to each other on the working side. On the balancing side, the Bennett path influences the height of the cusps

as well as their position. It is important to record the path of the Bennett movement and arrange the cusps of the teeth so that they can pass each other without clashing or climbing upon each other during function. At the same time, a continuous contact of these surfaces should be maintained in order they can efficiently perform their function of chewing without damage to the supporting structure⁽¹⁰⁾.

Bennett angle is the angle formed by the sagittal plane and the path of the advancing condyle during lateral mandibular movements as viewed in the horizontal plane⁽¹¹⁾. The protrusive angle is the angle formed between the condyles of the mandible and a horizontal line passing through the condyles' centers when the mandible moves forward of centric position (viewed in the horizontal plane)⁽¹⁰⁾.

An analogue of the condylar guidance on an articulator is considered to be a necessary requisite in prosthodontics. Condylar guidance is described as the mandibular guidance generated by the condyle and articular disc traversing the contour of the glenoid fossae or, synonymously, as the mechanical form located in the upper posterior region of an articulator that controls movement of the mobile member⁽¹²⁾.

The guidance inclination in semi-adjustable articulators is set either by individual protrusive or lateral inter-occlusal (IOC) registrations. Studies have shown the unreliability of recording and reproducing the condylar guidance on these instruments. Average value settings are used with mean inclinations of normal adult eminence morphology. Reported average IOC registrations values of the condylar guidance inclination vary from 21-64 degrees. Some advocated setting the condylar inclination at a flatter than average value to ensure disocclusion of the posterior teeth during excursions. However, if the individual inclination of the eminence is very steep or flat, guidance obtained from average value settings may differ sufficiently to cause problems in achieving particular clinical objectives, such as posterior disocclusion or balanced occlusion⁽¹²⁾.

The rotating condylar movement affects both the working and the nonworking sides but has its greatest effect on the working side. Semi-adjustable articulators do not have the ability to compensate for this movement. The fully adjustable articulators can be so modulated that the pathway of the rotating condyle on the articulator will duplicate that in the patient⁽¹³⁾.

The fully adjustable articulator permits adjustment of both the Bennett angle and the immediate side shift to duplicate these movements

of the patient's orbiting condyle. Many semi-adjustable articulators cannot duplicate this exact pathway since only flat surfaces (slot-track) are available to guide the condyle. When the exact characteristics of the orbiting condylar movement are duplicated, the correct groove placement and fossa width can be more precisely developed in a posterior fixed restoration⁽¹⁴⁾.

Ultrasonic mandibular movement recorders have been used to record sagittal condylar inclinations which showed no difference when compared to mechanical pantograph recordings although the latter persistently under recorded the immediate side shift⁽¹⁵⁾. Protrusive movement recordings are also important in fully edentulous complete denture wearers and to be taken into account during the final occlusal selective grinding for new sets of complete dentures⁽¹⁶⁾.

MATERIALS AND METHODS

Fifty adult patients (25 females and 25 males) aged 30 to 65 years participated in the present study. All subjects had generalized loss of incisal and occlusal morphology due to attrition and faceting of teeth, extensive defective restorations, or multiple missing teeth, associated with moderate or severe OVD collapse. They were recruited from those seeking fixed prosthodontic work at the department of conservative dentistry, College of Dentistry, University of Baghdad and they didn't present signs of muscular or articular pain according to the examination criteria of the multi-axial Research Diagnostic Criteria for TMDs (RDC/TMD) since myofascial pain of the masticatory muscles can affect mandibular range of motion and spatial relationship between upper and lower jaws⁽¹⁷⁾. Full series of periapical x-rays and a panoramic radiograph were taken for each patient.

For each patient, two sets of maxillary and mandibular irreversible hydrocolloid impressions (Tropicalgin Chromatic, Zhermack SpA, Italy) were made and converted into stone casts. Centric jaw relationship was made using Aluwax (Aluwax Dental Products Co, Michigan, USA) following Dawson's technique⁽⁶⁾ stressing that any perforated CR record due to premature tooth contact was discarded. All procedures for recording, mounting, and setting were done in the same session.

Arbitrary Mandibular Hinge Axis Location

After feeling the condyle rotation, the axis was located within an average of 2 mm or less since the axis generally occurs near the center of the

depression felt by the fingertip and it was marked as a dot by an indelible pencil⁽¹⁸⁾. A measurement method was applied by placing a ruler on an imaginary line running from the patient's superior border of the tragus of the ear to the outer canthus of the eye. The arbitrary axis was marked on the skin at eleven mm anterior to the tragus⁽¹⁹⁾.

Arbitrary Face-Bow Record

Orientation of dental casts within a full sized articulator is an essential element in producing a realistic analogue of a patient. This process is facilitated by using a face-bow to record the orientation of maxillary arch relative to a patient's transverse hinge axis of the mandible. The maxillary cast is then positioned within the articulator in the same anatomic relation. Face-bows were developed in conjunction with articulators to relate the maxillary arch to the axis of the condylar hinge in all three planes of space⁽²⁰⁾.

After achieving the Hanau face-bow record (Fascia Bow 132-2SM, Teledyne-Hanau Co., NY, USA), (Figure 1), the face-bow assembly was removed and the axis locator rods of the face-bow were placed to contact the outside of the metal posts of the condylar elements on both sides of the Hanau H-2 non-arcon articulator (Teledyne-Hanau Co., NY, USA) with the horizontal condylar guidance screws locked at 30°⁽²¹⁾. The upper cast was oriented and luted on the wax bite record of the maxillary arch for mounting (Fig.2). The middle groove on the incisal guide pin of the articulator was used as the 3rd point of reference for positioning the upper cast on the articulator⁽²²⁾.



Figure 1: Arbitrary Face-Bow Record.



Figure 2: Mounting the Upper Cast Using the Hanau Face-Bow.

Following that, the lower cast was mounted on the lower member of the articulator according to the CR record. Several protrusive bite records were made for each patient then the wax bite was removed from the mouth and trimmed back to the tips of the upper and lower cusps so that the stone cast was clearly visible where it contacted the wax bite⁽¹⁹⁾. All wax records were accepted when it was evident that the patient had protruded straight forward at least 6 mm anterior to centric relation, as shown on the Hanau articulator by the condylar spheres having moved anteriorly an equal distance of 6 mm on both sides⁽²³⁾.

The condylar inclination on the articulator was adjusted accordingly by releasing the condylar centric locks and the condyle path was altered to varying degrees of steepness until the maxillary cast fitted precisely into the wax bite record with no separation between the stone and the bite, i.e. separation at the distal part of the bite meant that the guidance was too steep, while any anterior separation between the cast and bite record could be a result from too flat condylar guidance⁽²¹⁾. After setting the horizontal condylar angles, their centric locks were tightened (Figure 3).



Figure 3: Setting the Horizontal Condylar Angle.

Bennett Angle Measurement:

The lateral condylar angle (Bennett angle) for each patient was calculated using the Hanau formula: L (lateral adjustment) = H (horizontal adjustment) / $8 + 12$ ⁽²⁴⁾ (Figs. 4a & b).



Figure 4a: Condylar Post Setting For Estimating Bennett Angle.



Figure 4b: Condylar Post Fixed at Estimated Bennett Angle.

Terminal Mandibular Hinge Axis Location:

It was performed by using the TMJ kinematic face-bow (TMJ Instrument Co. Inc, USA). When the axis locator pin of the kinematic face-bow stylus achieved a pure rotational movement during arcing the patient's mandible, the location of the pin point was marked on the flags' graph paper grids on both sides (Figure 5). When the axis was located, the flags were removed, styli moved out to mark its tip with graphite pencil and with holding the supported mandible in terminal hinge position; each stylus was moved toward the skin to mark it. The kinematic face-bow assembly was detached from the universal clutch which was taken out of the patient's mouth. The terminal hinge axis point was darkened with a red pen. After that, the interfacial width (IFW) was measured by an electronic caliper (Prokit's Industries Co, Ltd, Taiwan)⁽²⁵⁾.

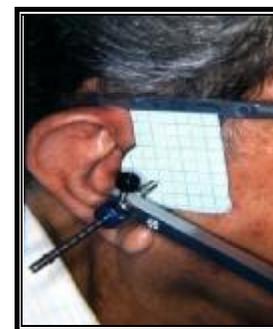


Figure 5: Marking Location of Pin Point on the Flag's Graph Paper.

The face-bow record was transferred to the TMJ Deluxe Model T-7 fully adjustable arcon articulator (TMJ Instrument Co, Inc, USA), and the ICD of each patient was determined and the condyle posts of the articulator were locked at the determined measurements⁽¹⁸⁾.

The maxillary cast of the patient was mounted on the maxillary member of the articulator according to the kinematic face-bow record then the mandibular cast was attached to the centric IOC record, placed between the two casts, and

mounted on the mandibular member of the articulator.

Verifying the protrusive angle of each patient to figure out the exact fossa analog degree which should be used for fossa molding for that case in order to duplicate that of the patient for constructing the full mouth rehabilitation prostheses ⁽²⁶⁾, a protrusive IOC record was registered for each patient then two square shaped transparent hard plastic protractors having a scale ranging from (0-60°) were attached to the articulator outside each of its fossa compartments in such a way that the protractor was close to the condylar stylus. The condyle pin was located at the center of the protractor in the terminal hinge position (Fig.6).



Figure 6: The condyle pin located at the protractor center.

Placing the protrusive IOC record in position between the maxillary and mandibular casts, the angle of eminentia was observed by sighting the center of the condyle pin through the transparent protractor and the protrusive angle of each patient was recorded (Figs.7a & b).



Figure 7 a: Estimation of the protrusive angle.



Figure 7 b: Estimation of protrusive Restorative Dentistry

angle by sighting the center of the condylar stylus through the protractor.

The Bennett angle of each condyle was calculated following Hanau formula. All angles were tabulated and statistically analyzed with a significance level of $p < 0.05$.

RESULTS

The descriptive statistics of the mean protrusive angle values showed that the highest was related to the male group recorded by the TMJ fully adjustable articulator (35.4°) followed by that scored by the female group (32.4°). The mean protrusive angle value of the male group scored by the Hanau H-2 articulator (30.0°) also was higher than the female group (25.6°), (Table1).

Table 1: Descriptive Statistics of the Mean Protrusive Angle Verified by TMJ & Hanau H-2 Articulators (in degrees).

Type of Articulator	Mean protrusive Angle	Mean	S.D.
TMJ	Female	32.4	8.180
	Male	35.4	9.345
Hanau H-2	Female	25.6	7.947
	Male	30.0	7.500
	Total	30.85	8.906

The ANOVA test results of the mean protrusive angle groups verified a highly significant difference between the groups combined, (Table 2).

Table 2: ANOVA Test Results of the Mean Protrusive Angle Groups.

Mean Protrusive Angle Groups	S.O.S	df	M.S.	Sig.
Between Groups	1284.750	3	428.250	0.001
Within Groups	6568.000	96	68.417	
Total	7852.750	99		

The descriptive statistics of the difference of mean values of protrusive angles scored by the TMJ articulator and the Hanau H-2 articulator for the female patients was higher (6.8°) than for the males (5.4°) as shown in Table 3 & Fig. 1; a finding that was statistically not significant (Table 4).

Table 3: Descriptive Statistics of the Difference of Protrusive Angle Mean Values Verified by TMJ & Hanau H-2 Articulators (in degrees).

Tested Groups	Mean Protrusive angle, TMJ	Mean Protrusive angle, Hanau H-2	Mean Diff. of Protrusive angle, TMJ & Hanau H-2	S.D.
Female	32.4	25.6	6.8	3.50
Male	35.4	30.0	5.4	4.06
Total	30.85		6.1	3.81

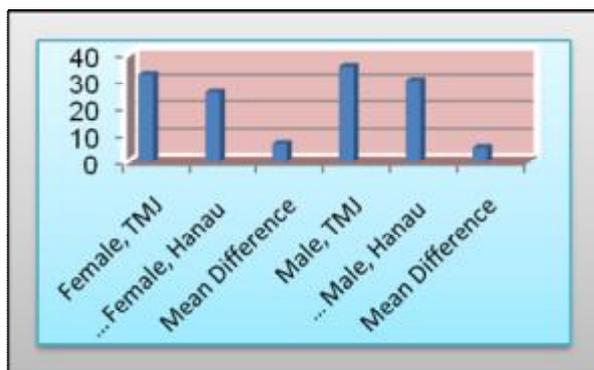


Figure 1: The Mean Protrusive Angles Verified by TMJ & Hanau H-2 Articulators & the Mean Differences of Females & Males (in degrees).

Table 4: ANOVA Test Results of the Difference in Protrusive Angle Means Verified by TMJ & Hanau H-2 Articulators.

Mean difference	S.O.S	df	M.S.	Sig.
Between Groups	24.5	1	24.500	0.198 NS
Within Groups	690.0	48	14.375	
Total	714.5	49		

Concerning the Bennett angle, the highest mean (16.42°) which was related to the male group was scored by the TMJ articulator, while the lowest one (15.2°) which belonged to the female group was scored by the Hanau H-2 articulator (Table 5).

Table 5: Descriptive Statistics of Mean Bennett Angles of Females & Males, Verified by TMJ & Hanau H-2 Articulators in degrees.

Groups of mean Bennett Angle	Mean	S.D	Min.	Max.
Female, TMJ	16.05	1.022	14.5	18.25
Female, Hanau H-2	15.20	0.994	13.88	17.63
Male, TMJ	16.42	1.167	14.50	18.25
Male, Hanau H-2	15.75	0.937	13.88	17.00
Total	15.85	1.113	13.88	18.25

The ANOVA test results showed a highly significant difference (P<0.001) between the groups, (Table 6).

Table 6: ANOVA test Results of Mean Bennett Angles.

Mean	S.O.S	df	M.S.	Sig.
Between Groups (Combined)	20.055	3	6.685	0.001 HS
Within Groups	102.645	96	1.069	
Total	122.700	99		

Concerning protrusive angles, the total means of female patients (31.90°) and males (35.40°) verified by the TMJ articulator were higher than those scored by the Hanau H-2 articulator (26.70° & 30.40°). As a consequence, the total means of protrusive angles verified by the TMJ articulator (33.67°) were more than those of the Hanau H-2 articulator (28.55°). For the right and left TMJs, group means verified by both articulators were close to each other with the left joint score being more than the right when using the TMJ articulator (34.30° vs. 33.04°). Also, the left joint group mean was higher than the right joint when using the Hanau H-2 articulator (28.70 vs.28.40°), (Table 7).

Comparing the Bennett angles of the right and left joints, the means of the female group determined by the TMJ articulator were of the same value (16.05°) while in the male group, the left joint angles (16.52°) were more than the right (16.32°) with a difference of 0.2°. Means verified

by the Hanau H-2 articulator showed that the angles scored by the females' right joints (15.35°) were more than their left joints (15.02°) with a difference of 0.33°. The opposite occurred with the males where their left joint Bennett angles (15.75°) were more than their right joints (15.72°) with a difference of 0.03°. The males' right and left TMJs had Bennett angles more than their equivalents of the female patients scored by the two articulator systems (Table 8).

Table 7: Descriptive Statistics of the Detailed Group Mean Values of the Female and Male Patients Concerning the Right and Left Joints' Protrusive Angles.

Groups (Mean)	Protrusive angle°		Total mean		
Female	TMJ	R	31.48	31.90	
		L	32.40		
	H-2	R	26.80		26.70
		L	26.60		
Male	TMJ	R	34.60	35.40	
		L	36.20		
	H-2	R	30.00		30.40
		L	30.80		
Groups mean	TMJ	R	33.04	33.67	
		L	34.30		
Groups mean	H-2	R	28.40	28.55	
		L	28.70		

Table 8: Descriptive Statistics of the Detailed Group Mean Values of the Female and Male Patients Concerning the Right and Left Joints' Bennett Angles.

Groups (Mean)	Bennett angle°		Total mean		
Female	TMJ	R	16.05	16.05	
		L	16.05		
	H-2	R	15.35		15.19
		L	15.02		
Male	TMJ	R	16.32	16.42	
		L	16.52		
	H-2	R	15.72		15.74
		L	15.75		
Groups mean	TMJ	R	16.18	16.23	
		L	16.28		
Groups mean	H-2	R	15.54	15.46	
		L	15.39		

DISCUSSION

Horizontal Condylar (Protrusive) Angle:

The Hanau H-2 semi-adjustable non-arcon articulator used in this study revealed that the groups' mean values of left side protrusive angles

were equal to (28.70°) which was smaller than that scored by the Dentatus ARH non-arcon semi-adjustable articulator (43.83°) tested in dos Santos and Ash study (27). Also, the right side groups' mean values of protrusive angles of both sexes (28.40°) were smaller than their right side mean angles (44.70°). Although the Dentatus ARH articulator is considered the Swedish copy of the Hanau H-2 articulator, the differences in these values could be related to the attempt of dos Santos and Ash to duplicate the jaw movement tracings of the pantograph in the semi-adjustable articulator, a conclusion in which they stressed that their study indicated that a pantographic instrument is too critical to be used to set a semi-adjustable articulator.

The results of the current study went along with those of El-Gheriani and Winstanley (28) who reported the presence of great variation in condylar inclinations between the studied patients on one side and between the left and right sides of the same patient. Such variation could be explained in that the protrusive and retrusive movements, generated by condylar translation, are influenced by the shape of the eminentia and their maximal range is restricted by the mechanical constraint of the temporomandibular ligaments, namely the stylomandibular ligament and capsule causing the condyles to have limited rotation during protrusion and retrusion (29). This has been clearly explained in that the downward inclination of the articular eminence makes it plausible that the condyle is slightly pressed against the articular eminence during the main translatory protrusive movement and opening movement which are considered of a compressive nature (30).

In current study, the Hanau H-2 semi-adjustable articulator was chosen since the data obtained by this articulator regarding the sagittal condylar inclination using the protrusive IOC record has been compared with that obtained by a jaw-tracking system (31) where the Hanau H-2 articulator was recommended for accurate measurements of the sagittal condylar path inclination. In a previous study, Taylor et al. (32) reported that the protrusive IOC record was a generally acceptable way for adjusting the horizontal condylar inclination of the Hanau H-2 and Dentatus semi-adjustable articulators. The use of IOC check bite registrations for programming semiadjustable articulators has been found as an easier alternative to the axiograph (33).

Since many condylar path recordings have pronounced curvatures, it's doubtful that an articulator can be programmed to reproduce the condylar inclination by assigning fixed values to

it, thus a custom-fossa insert that could be shaped to follow the curvature of the condylar path would be more accurate⁽²⁸⁾.

As an alternative to the IOC registration methods, average values have been used to set the condylar guidance of articulators in referral to mean inclinations of normal adult eminence morphology⁽³⁴⁾. As a consequence, setting the condylar inclination at a flatter than average value was advocated to ensure disocclusion of the posterior teeth during excursions⁽³⁵⁾. However, if the individual inclination of the eminence is very steep or flat, guidance obtained from average value settings may differ sufficiently to cause problems in achieving particular clinical objectives, such as posterior disocclusion or balanced occlusion⁽¹²⁾.

Bennett Angle

Significant and highly significant differences were also present between male and female groups which could generally be related to anatomical variations concerning the shape of condylar heads and fossae curvatures.

Generally, the males' right and left TMJs had Bennett angles more than their equivalents of the female patients scored by the two articulator systems used in this study, a finding which could be due to increased laxity of the temporomandibular ligaments⁽²⁹⁾ and/or anatomical variations in the inclination of the eminentia⁽¹²⁾.

The explanation for the differences between the Bennett angle mean values determined by the TMJ fully adjustable articulator system with those of the Hanau H-2 semi-adjustable articulator system lies in the different techniques utilized in each system starting from locating the arbitrary and terminal hinge axes and determining the protrusive condylar angles on which estimation of the patients' Bennett angles were entirely dependent on. It has been reported that the rotating condylar movement affects both the working and the nonworking sides but has its greatest effect on the working side. Semi-adjustable articulators do not have the ability to compensate for this movement. The fully adjustable articulators can be modulated so that the pathway of the rotating condyle on the articulator can duplicate that of the patient⁽¹⁴⁾.

The right and left Bennett angle groups' mean values recorded by the Hanau H-2 non-arcon semi-adjustable articulator in this study (15.54° & 15.39°) were greater than those recorded by the Dentatus ARH non-arcon semi-adjustable articulator (12.80° for right side & 12.26° for left side) in dos Santos and Ash study⁽²⁷⁾, a variation

which might be related to their attempt to duplicate the jaw movement tracings of the pantograph in the semi-adjustable articulator.

In other words, the condyles usually follow a convex path (curve), on any but the most damaged eminentia, which isn't copied in the slot-track (straight-line) articulators which don't reflect the medial curvature of the non-working horizontal condylar path⁽³⁶⁾.

Theusner et al.⁽²⁹⁾ showed a maximum range of 12.7° for the right joint of their asymptomatic patients while a range of 12.2° maximum existed for the left joint. In their study, the group means of Bennett angles of the right joint were significantly larger than those of the left joint. The terminal hinge axis was located with the "SAS Hinge Axis Tracing System". On the other hand, the results of the current study indicated that the TMJ articulator system, in which a kinematic hinge axis locator was used, has shown that the group means of the female and male Bennett angles were close to each other. The left and right joint group means of both sexes were also close to each other (16.28° & 16.18°) but were more than those of Theusner et al.⁽²⁹⁾ study. The difference between the two studies may be due to the different estimation techniques of the Bennett angles since Theusner et al. applied a "modified SAS electronic axiograph" for their different mandibular movement measurements while in this study, the Bennett angles were verified by applying the Hanau formula in which the actual protrusive condylar angles verified by the axis protractors were incorporated.

On the other hand, no statistical differences were located between the Bennett angles of the females and males that were verified by the TMJ fully adjustable articulator while significant differences were located between the two sexes when using the Hanau H-2 semi-adjustable articulator. After comparing the mean values, the Bennett angles of both sexes verified by the TMJ articulator were statistically significant compared to those verified by the Hanau H-2 articulator, a finding that was related to the high precision degree which the axis protractors had provided the TMJ articulator with in order to accurately locate the protrusive angles of each patient involved in this study.

The results of the current study coincide with that patients acquiring excessive Bennett movement and little or no anterior guidance present the greatest challenge in occlusal rehabilitation procedures because the cusp movement pathways of their posterior teeth are very shallow and the elimination of eccentric cusp

interferences can be very difficult. The completely adjustable articulators would be most helpful for these types of patients.

As conclusions

1. Male protrusive angles were higher than females with the fully adjustable articulator scoring higher mean values than the semi-adjustable articulator.
2. Non-significant differences existed between the protrusive angles of male and female patients scored by the fully adjustable articulator while significant differences were located using the semi-adjustable articulator.
3. Generally, the males' right and left condyles had Bennett angles greater than their female equivalents.
4. The highest Bennett angle mean values were scored by the male group of the fully adjustable articulator while the lowest belonged to the female group of the semi-adjustable articulator.
5. A fully adjustable articulator that can provide precision estimation of the horizontal condylar angles and Bennett angles would be most helpful in treating full mouth rehabilitation cases.

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