AL-AZHAR
Dental Journal
For Girls

The Official Publication
of The Faculty of Dental
Medicine For Girls,
Al-Azhar University
Cairo, Egypt.

Print ISSN 2537-0308 • Online ISSN 2537-0316

ADJ-for Girls, Vol. 9, No. 4, October (2022) — PP. 571:580

Effect of Different Horizontal Condylar Guidance Registration Methods and Articulators on Bilateral Balanced Occlusion of Complete Denture

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Codex : 03/22.10

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http://adjg.journals.ekb.eg

DOI: 10.21608/adjg.2022.76239.1387

Restorative Dentistry
(Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

ABSTRACT

Purpose: To evaluate the effect of different horizontal condylar guidance registration methods and articulators on bilateral balanced occlusion of complete denture. **Materials and Methods:** Twelve completely edentulous patients with ages ranging from 50-60 years old were selected from the outpatient clinics of the Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University. Twelve complete dentures were constructed according to the balanced occlusal concept and then duplicated for experimental work. Horizontal condylar guidance angles were measured using three different methods; the protrusive interocclusal wax record method, tracing method, and Cone Beam Computed Tomography (CBCT) scan. The angles were adjusted on two types of articulators; Arcon and non-Arcon articulators. The effect of each method and the effect of the two types of articulators on bilateral balanced occlusion were studied. **Results:** The result of this study showed that there was no significant difference in bilateral balanced occlusion when using different types of articulators or different horizontal condylar guidance registration methods during the construction of complete denture. **Conclusion:** Within the limitation of this study, it can be concluded that the Hanau system with the wax protrusive record may be the most practical way to obtain the desired relative horizontal condylar angle.

KEYWORDS

Balanced Occlusion, Complete Denture, Horizontal Condylar Guidance, Articulators

- **Paper extracted from Master thesis titled "**Effect of Different Horizontal Condylar Guidance Registration Methods and Articulators on Bilateral Balanced Occlusion of Complete Denture".

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INTRODUCTION

The successful treatment outcome for edentulous patients is obtained by providing harmony between the occlusal surfaces of the artificial teeth and the condylar paths which plays a significant role in the reestablishment of the stomatognathic system function and preservation of alveolar bone[1].

During several mandibular movements, the condyle travels a unique path in the temporomandibular joint which is known as the condylar path and it is peculiar to each individual[2].Condylar guidance is the angle at which the condyle moves away from the horizontal reference plane[3].Also, it can be defined as the mechanical form at the posterior part of an articulator that controls the movement of its movable element[2].

Accurate simulation of the patient's condylar path on the articulator (condylar guidance) with the help of its face-bow system creates harmonious tooth contacts without occlusal interferences during mandibular movements[4].

Semi-adjustable articulators are widely used to simulate certain mandibular movement and condylar pathways due to their ease in programming. They are classified as Arcon and Non-Arcon types which differ in the structure of a mechanical joint[2,5]. The Arcon articulator can further reflect the anatomy of the human joint as the mechanical condyles are located in the lower part of the articulator which corresponds to the mandible, and artificial fossa articularis are in the upper part of the articulator, which corresponds to the maxilla. In contrast to human joint, the position of the mechanical joint components is reversed in the Non-Arcon type[6].

Face-bow is a substantial accessory of semi-adjustable articulators which replicate the three-dimensional spatial relationship of the maxillary cast to the cranial structures replicated to the articulator[7].

The condylar guidance inclination can be adjusted on semi-adjustable articulators by various intraoral and extraoral methods or by radiographic methods as they involve stable bony landmarks and can be standardized. The choice of material used for records, the method of procedure, and the individual skills are important factors that affect the accuracy of the articular adjustment[8].

To achieve a successful conventional complete denture fabrication, occlusion must be carefully considered as it provides an even distribution of masticatory forces, better retention, stabilization of denture bases, and patient's general comfort and satisfaction with denture[9].This clinical study is oriented towards evaluating the effect of different horizontal condylar guidance registration methods and articulators on bilateral balanced occlusion of complete denture.

MATERIAL AND METHODS

Twelve completely edentulous patients were selected from the outpatient clinics of the Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University. The patients were in the age of 50-60 years, residual alveolar ridges of maxilla and mandible covered by healthy, firm, compressible mucosa, have Angle's class I jaw relation. Any local or systemic diseases and any temporomandibular joint disorders such as clicking, limitation of opening or mandibular movement, muscles spasm or tenderness, and mandibular deviation were excluded. Before starting the study, written consent was obtained from all the patients regarding the procedure with the approval of the Research Ethics Committee (REC) of the Faculty of Dental Medicine for Girls, Al-Azhar University (REC-PR-21-02).

Twelve complete dentures were constructed for each patient. Alginate impression material (Cavex, Holland) were used to make upper and lower impression and then poured with dental plaster (Rapid stone keer, USA) to obtain the primary casts then the final impression was made using green stick compound(Hiflex, India) for border molding and

zinc oxide and eugenol impression material (Cavex, Holland).Jaw relation and face-bow transfer were done and the maxillary cast was mounted on Arcon semi-adjustable articulator (Bio-Art corporation, Brazil).

Centric relation record was recorded using interocclusal wax record then upper record block was separated from the lower record block and was kept in cold water then protrusive interocclusal wax record was recorded by adding 4mm of softened pink wax(Cavex, Holland) to the lower occlusion block. The patient was asked to protrude the mandible about 6mm and close the record blocks together in that position. The protrusive interocclusal wax records also were separated from each other and kept in cold water.

The lower cast was mounted to the lower member of the articulator using the centric interocclusal wax record. The horizontal condylar guidance was adjusted on the articulator using the protrusive interocclusal wax record. Artificial teeth (Acrostone, Egypt) were arranged to balanced articulation. The denture was waxed up, tried at the patient mouth. Plaster index was made by removing the lower cast from the articulator and return the upper waxed-up denture to the upper cast on the articulator. A remounting platform was attached to the lower member of the articulator. Plaster (Rapid stone keer, USA) was mixed and placed over the remounting plate and the upper member of the articulator with the upper waxed denture was closed on the plaster. After setting of plaster the articulator was opened and any excess plaster than 2-3 mm in the teeth imprint was removed. Waxed up denture was processed into heat-cured acrylic resin (Acrostone, Egypt), finished, and polished.

The finished denture was clinically remounted and occlusal adjustment was done to eliminate any cuspal interference in protrusive and lateral excursions and to establish an even bilateral balanced occlusal contact. The denture was duplicated for experimental work.

In this study, the horizontal condylar angle was calculated using three methods: interocclusal wax record method (which was taken during the complete denture construction), graphic tracing method, and Cone Beam Computerized Tomography (CBCT).

Graphic tracing method:

A quick set recorder (Whip mix corporation, USA) was used to trace and measure the protrusive pathway. The orbital was palpated and a point opposite to it was marked on a patient's face. The reference line (axis-orbital line) is drawn on the patient's face. The flag holder frame of the qiuck set recorder was adjusted in width to allow positioning of each flag as close as possible to the patient's head. A graphic card was attached to each flag. The bite fork of the quick set recorder was attached to the lower denture and was inserted into the patient's mouth and fixed to the mandible by a mandibular clamp.

The patient's jaw was guided into the most retruded position, and then the toggle assembly was tightened. A lead holder with sharpened lead was placed onto each pointer. The patient was seated in a comfortable upright position and was instructed to protrude the mandible (Maximum protrusion) to trace the condylar path on the graphic cards (Fig. 1,a). The recording papers were placed two times and protrusive movement was repeated each time to produce three graphical recordings of the horizontal condylar path on each side.

Enlarged photocopies (10 times magnification) of the graphic tracings were used to determine the condylar angle mathematically. Four arbitrary points (1-4) were selected on each curve to include the whole curve. From points (2-4) horizontal lines were drawn (parallel to the axis-orbital plane) and from points (1-3) vertical lines were dropped into the horizontal lines. The slope of the angles (a, b, and c) was calculated from the following equation: Slope = vertical distance ÷ horizontal distance

The angles were calculated by reversing its slope using a scientific calculator (Casio, FX-82C, Japan). The mean of the three values for each curve was calculated and the mean of the three curve angulations was considered as the condylar inclination of this side.

Cone Beam Computerized Tomography (CBCT) scanning:

CBCT CRANEX 3Dx machine was used in this study. Two images were taken for each patient; one in a centric position and another one in a protrusive position. The patient was placed on the machine in an upright position and the field of view was adjusted guided by laser lines (Fig. 1,b). Then the patient was asked to close his mouth in centric occlusion then moves his mandible protrusively. Three-dimensional images the outline of condyles in both centric and protrusive positions are digitally delineated.

Both images were superimposed together in three dimensions (Fig.1c). Frankfort line drawing from the deepest point of inferior orbital rim to the highest point of the external auditory meatus. The protrusive condylar path was obtained by drawing a line tangent to the condyles in maximum intercuspation and in a protrusive position. The angle between two tanged lines was measured. This procedure was made twice for each balancing condyle of the same patient and the mean angle was obtained and tabulated. The measured angles tabulated for each patient then applied on the articulators to record the balanced occlusion.

Preparation of the experimental denture for test:

The duplicated denture was remounted twice, one on the non-Arcon articulator and another one on the Arcon articulator following the same method for clinical remounting of the original denture. The occlusal adjustment was carried out to establish even bilateral occlusal contact and remove any interference in protrusive and lateral relation.

Each articulator was locked in centric relation and both maxillary and mandibular second molars were removed from the denture. Auto polymerizing acrylic resin (Acrostone, Egypt) was used to fix one-centimeter square metal plates in the lower second molar position. One square cm recording paper was attached to the metal plates. A metal tube was fixed by auto polymerizing acrylic resin in the place of the maxillary second molar (Fig. 1d).

The effect of the horizontal condylar path inclination records on complete denture balancing occlusion:

For the right side, lateral condylar guidance was adjusted to the value calculated from the Hanau equation. The left horizontal and lateral condylar guidance were adjusted to zero degree. The right horizontal condylar guidance of the articulator was adjusted three times using the angles determined by the interocclusal wax record, tracing method, and radiographic method.

The upper bow of the articulator was moved backward and to the left (working side) till the upper buccal and lower buccal cusps were in a line then the centric lock was locked. Using an indelible pencil, a mark was marked on the incisal table to determine the position of the incisal pin at cusp to cusp position. This mark is used to adjust the amount of lateral movement in subsequent records and measurements.

Mesiodistal and buccolingual perpendicular lines were drawn and pass approximately through the center of the recording paper. After each horizontal condylar guidance adjustment, a metal needle with a 0.22 mm pointed end was inserted inside the metal tube in the maxillary second molar at the right side from the above downwards till it was indenting the recording paper placed on the plate at the lower second molar area (Fig. 1e).

The distance from each indentation to the mesiodistal and buccolingual lines and from the indentation to the meeting point of the mesiodistal

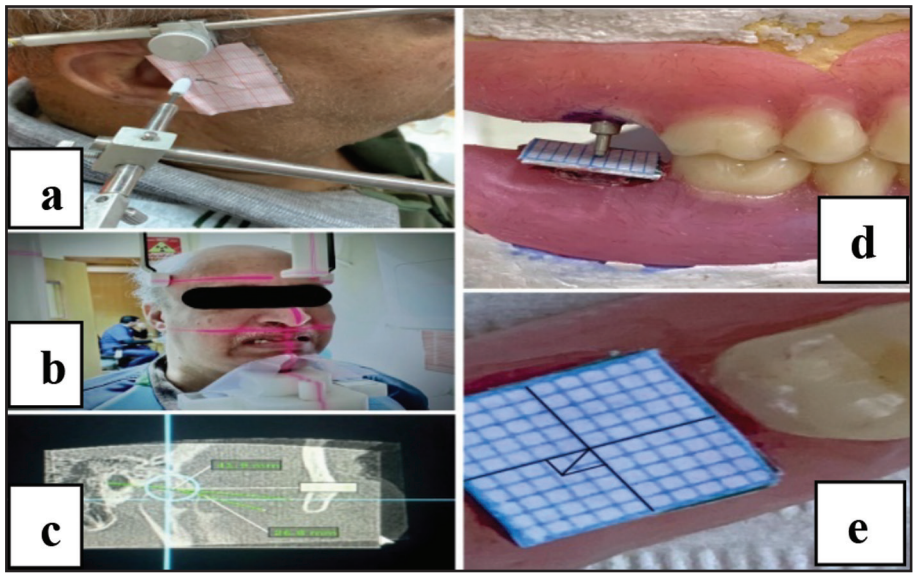

Figure (1): **a.**Graphic tracing;The patient was instructed to protrude the mandible (Maximum protrusion) to trace the condylar path on the graphic cards. **b.**The patient was placed on the machine in an upright position and the field of view was adjusted guided by laser lines. **c.** Superimposition of a centric and protrusive condylar image showing condylar path angle. **d.**a metal needle with 0.22 mm pointed end was inserted inside the metal tube in the maxillary second molar at the right side from the above downwards till it was indenting the recording paper placed on the plate at the lower second molar area. **e.** Mesiodistal and buccolingual perpendicular lines were drawn parallel to the borders of the plate at the lower second molars.

and buccolingual perpendicular lines were measured by a digital caliper and recorded. The measurements of the buccolingual distance were considered +ve if the indentation was to the buccal to the mesiodistal line and –ve if it was to the lingual. Also, the measurements of the mesiodistal distance were considered +ve if the indentation was mesial to the buccolingual line and –ve if it was to the distal. The same procedures of right side record and measurements were followed for the left side.

RESULTS

Horizontal guidance angle

Bio-Art articulator:

Mean, Standard deviation (SD) values of horizontal guidance angle ,and results of paired t-test for the Bio-Art articulator were presented in table (1).

- Regarding the right side, a comparison between the interocclusal record and tracing method revealed that tracing record (36.14±4.98) had a significantly higher value than the interocclusal record (26.57±3.95) (p=0.007). But, when comparison was made between interocclusal records and CBCT scan, interocclusal records (26.57±3.95) had a higher value than CBCT records (24.79±3.22) yet there was no statistically significant difference (p=0.401).
- For the left side, tracing record (30.71±2.81) had a significantly higher value than interocclusal records (21.63±4.14) (p=0.002). Interocclusal records (21.63±4.14) had a higher value than CBCT records (18.74±3.78) yet there was no statistically significant difference (p=0.182).

Hanau articulator:

Mean, Standard deviation (SD) values of horizontal guidance angle ,and results of paired t-test for the Hanau articulator were presented in table (1).

- Regarding the right side, a comparison between the interocclusal record and tracing method revealed that tracing records (37.57±2.30) had a significantly higher value than interocclusal records (32.14±3.76) (p=0.013). When the comparison was made between the interocclusal records and CBCT scan, interocclusal records (32.14±3.76) had a significantly higher value than CBCT records (24.79±3.22) (p=0.022).

Table (1) *Mean, Standard deviation (SD) values of horizontal guidance angle for Bio-Art and Hanau articulators*

Side	Comparison	Horizontal guidance angle for Bio-Art articulator (mean±SD)		t-value	p-value	Horizontal guidance angle for Hanau articulator (mean±SD)		t-value	p-value
		Group (I)	Group (II)			Group (I)	Group (II)		
Right	Interocclusal vs Tracing	26.57±3.95	36.14±4.98	-4.01	0.007*	32.14±3.76	37.57±2.30	-3.49	0.013*
	Interocclusal vs CBCT	26.57±3.95	24.79±3.22	0.904	0.401ns	32.14±3.76	24.79±3.22	3.05	0.022*
Left	Interocclusal vs Tracing	21.63±4.14	30.71±2.81	-5.38	0.002*	34.43±3.74	30.71±2.81	2.01	0.091ns
	Interocclusal vs CBCT	21.63±4.14	18.74±3.78	1.51	0.182ns	34.43±3.74	18.74±3.78	5.84	0.001*

**; significant (p≤0.05), ns; non-significant (p>0.05)*

- On the other side, interocclusal records (34.43±3.74) had a higher value than tracing records (30.71±2,81) yet there was no statistically significant difference (p=0.091). Interocclusal records (34.43±3.74) had a significantly higher value than CBCT records (18.74±3.78) (p=0.001).

Balanced contact measurements with different horizontal condylar path inclination records:

Bio-Art articulator:

Mean, Standard deviation (SD) values of balanced contact measurements with different horizontal condylar path inclination records, and results of paired t-test for Bioart articulator records were presented in table (2).

For the right side:

- Comparison between the measurements of the mesiodistal distance of the interocclusal method and the measurements of the tracing method showed that the tracing record (1.80±0.26) had a higher value than the interocclusal (1.77±0.18) yet there was no statistically significant difference (p=0.849). When comparison was made between CBCT measurements and interocclusal record, CBCT record (1.83±0.23) had a higher value than interocclusal record (1.77±0.18) yet there was no statistically significant difference (p=0.622).
- When the measurements of the buccolingual distance of interocclusal records were compared with the measurements of the tracing method, the interocclusal record (1.58±0.26) had a higher value than the tracing record (1.54±0.23) yet there was no statistically significant difference (p=0.663). Buccolingual measurements of interocclusal record (1.58±0.26) had a higher value than CBCT record (1.51±0.13) yet there was no statistically significant difference (p=0.610).
- Direct measurements of the interocclusal record (2.31±0.24) had a higher value than the tracing record (2.25±0.28) yet there was no statistically significant difference (p=0.578). Direct measurements of interocclusal record (2.31±0.24) had a higher value than CBCT record (2.12±0.28) yet there was no statistically significant difference (p=0.099).

For the left side:

- The mesiodistal measurements of the interocclusal record (1.80±0.31) had a higher value

than the measurements of the tracing method(1.66±0.29) yet there was no statistically significant difference (p=0.450). The mesiodistal measurements of the CBCT record (1.83±0.38) had a higher value than the measurements of the interocclusal record (1.80±0.31) yet there was no statistically significant difference (p=0.824).

- The buccolingual measurements of the interocclusal record (1.51±0.31) had a higher value than the measurements of the tracing record (1.50±0.19) yet there was no statistically significant difference (p=0.945). The measurements of the CBCT record (1.66±0.31) had a higher value than the measurements of the interocclusal record (1.51±0.31) yet there was no statistically significant difference (p=0.245).
- The direct measurements of the interocclusal record (2.24±0.18) had a higher value than the measurements of the tracing method (2.15±0.28) yet there was no statistically significant difference (p=0.512). The measurements of the CBCT record (2.41±0.35) had a higher value than the interocclusal record (2.24±0.18) yet there was no statistically significant difference (p=0.201).

Hanau articulator:

Mean, Standard deviation (SD) values of balanced contact measurements with different horizontal condylar path inclination records and results of paired t-test for Hanu articulator records were presented in table (2).

For the Right side:

- Comparison between the mesiodistal measurements of the interocclusal and tracing method showed that the interocclusal record (2.07±0.35) had a higher value than the tracing record (1.89±0.42) yet there was no statistically significant difference (p=0.401). The measurements of the interocclusal record (2.07±0.35) had a higher value than the CBCT record (2.06±0.24) yet there was no statistically significant difference (p=0.956).
- Buccolingual measurements of interocclusal record (1.61±0.37) had a higher value than the measurements of tracing record (1.59±0.27) yet there was no statistically significant difference (p=0.544). The measurements of the interocclusal record (1.61±0.37) had a higher value than the CBCT record (1.54±0.47) yet there was no statistically significant difference (p=0.428).
- Direct measurements of the Interocclusal record (2.22±0.34) had a higher value than the tracing record (2.13±0.43) yet there was no statistically significant difference (p=0.603). Direct measurements of CBCT record (2.23±0.31) had a higher value than the measurement of interocclusal record (2.22±0.34) yet there was no statistically significant difference (p=0.965).

For the left side:

- For the mesiodistal measurements, the tracing record (2.10±0.62) had a higher value than the interocclusal record (1.95±0.33) yet there was no statistically significant difference (p=0.501). CBCT record (2.07±0.62) had a higher value than the interocclusal record (1.95±0.33) yet there was no statistically significant difference (p=0.629).
- For the buccolingual measurements, the measurements of the interocclusal record (1.80±0.63) had a higher value than the tracing record (1.40±0.34) yet there was no statistically significant difference difference (p=0.055). Interocclusal record (1.80±0.63) had a higher value than CBCT record (1.50±0.35) yet there was no statistically significant difference (p=0.220).
- The direct measurements of the interocclusal record (2.31±0.53) had a higher value than the measurements of the tracing record (2.23±0.41) yet there was no statistically significant difference (p=0.670).The direct measurements of the CBCT record (2.34±0.80) had a higher value than the measurements of the interocclusal record (2.31±0.53) yet there was no statistically significant difference (p=0.943).

Table (2) *Mean, Standard deviation (SD) values of balanced contact measurements with different horizontal condylar path inclination records for Bio-Art and Hanau articulators*

Side	Measure	Comparisons	Horizontal path inclination records for Bio-Art articulator (mean±SD)		t-value	P-value	Horizontal path inclination records for Hanau articulator (mean±SD)		t-value	P-value
			Group (I)	Group (II)			Group (I)	Group (II)		
Right	MD	Interocclusal vs Tracing	1.77±0.18	1.80±0.26	-0.20	0.849ns	2.07±0.35	1.89±0.42	0.90	0.401ns
		Interocclusal vs CBCT	1.77±0.18	1.83±0.23	0.52	0.622ns	2.07±0.35	2.06±0.24	-0.06	0.956ns
	BL	Interocclusal vs Tracing	1.58±0.26	1.54±0.23	0.46	0.663ns	1.61±0.37	1.59±0.27	0.64	0.544ns
		Interocclusal vs CBCT	1.58±0.26	1.51±0.13	-0.54	0.610ns	1.61±0.37	1.54±0.47	-0.85	0.428ns
	Direct	Interocclusal vs Tracing	2.31±0.24	2.25±0.28	0.59	0.578ns	2.22±0.34	2.13±0.43	0.55	0.603ns
		Interocclusal vs CBCT	2.31±0.24	2.12±0.28	-1.95	0.099ns	2.22±0.34	2.23±0.31	0.05	0.965ns
Left	MD	Interocclusal vs Tracing	1.80±0.31	1.66±0.29	0.81	0.450ns	1.95±0.33	2.10±0.62	-0.72	0.501ns
		Interocclusal vs CBCT	1.80±0.31	1.83±0.38	0.23	0.824ns	1.95±0.33	2.07±0.62	0.51	0.629ns
	BL	Interocclusal vs Tracing	1.51±0.31	1.50±0.19	0.07	0.945ns	1.80±0.63	1.40±0.34	2.38	0.055ns
		Interocclusal vs CBCT	1.51±0.31	1.66±0.31	1.29	0.245ns	1.80±0.63	1.50±0.35	-1.37	0.220ns
	Direct	Interocclusal vs Tracing	2.24±0.18	2.15±0.28	0.70	0.512ns	2.31±0.53	2.23±0.41	0.45	0.670ns
		Interocclusal vs CBCT	2.24±0.18	2.41±0.35	1.43	0.201ns	2.31±0.53	2.34±0.80	0.07	0.943ns

ns; non-significant (p>0.05)

DISCUSSION

Statistically significant differences were found between Hanau 92 giving the highest registrations and Bio-Art A7 Plus the lowest. It has been found that when a protrusive record of specific thickness is used to program the articulator, the condylar inclination of mechanical fossae of the non-Arcon design changes regarding the maxillary occlusal plane when the articulator is opened, which can lead to errors. Other study concluded that the mean difference in horizontal condylar guidance values obtained from non-Arcon and Arcon articulators was highly significant indicating a low level of reproducibility [10].

Protrusive interocclusal records are the most common method used to adjust different types of semi-adjustable articulators for measuring the horizontal condylar guidance; because it is

simple, easy, quick, not expensive, and does not require specialized devices or machinery[11].During registration of protrusive interocclusal records, it is important to keep the distance of protrusion the same for both articulatorsbecause the horizontal condylar guidance changes with the degree of protrusion. Accordingly, the protrusive interocclusal wax record was obtained at 6 mm of protrusive movement[8].

High levels of variability were seen in condylar guidance between the protrusive interocclusal wax method and other methods. Measurements of the extraoral tracing of the horizontal condylar path gave a higher significant difference than the protrusive interocclusal wax method, this aligns with a previous study [12]. Condyle moves through a steeper slop in the first 3 mm which the wax record did not capture. The extraoral tracing records the whole condylar pathway and shows the mean measurement according to the amount of condylar Travers[12].

Compared to clinical methods, the radiographic method is more accurate and an alternative method of ascertaining horizontal condylar guidance values[13]. Recently, CBCT scan produces 3D multiplanar sections which provide an improved anatomic overview of the condylar pathway without the superimpositions found in the 2D radiographs[14].

Horizontal condylar guidance values obtained from the CBCT scan were lower than values obtained from the protrusive interocclusal wax method with no significant difference in Bioart articulator in both sides. However, in Hanau articulator, there was a significant difference in values between the protrusive interocclusal wax method and CBCT on both sides.

Contrary to our results, it has been reported that SCGA values obtained from CBCT measurements were higher than those from protrusive occlusal records and similar results were also tested by another study[15].

The present study is inconsistent with the previous studies showing that protrusive interocclusal methods of recording horizontal condylar angles have a lower level of reproducibility and are subject to variation of an instrument, operator, and occlusal records. One important reason for this inconsistency may be that horizontal condylar angle changes with the degree of protrusion, and the intra-oral record represents only one point along the condylar path[13,15].As regards studying the effect of using these horizontal condylar registration methods and articulators on bilateral balanced occlusion, it was found that there was no significant difference.

CONCLUSION

This studyshowed that there is no statically significant difference in balanced occlusion when using different types of articulators or different horizontal condylar guidance registration methods.

ACKNOWLEDGEMENT

Thanks to Dr. Hager Fawzan El-sadany, Lecturer of Removable Prosthodontics, Faculty of Dental Medicine, Al Azhar University for her support during the preparation of this manuscript.

RECOMMENDATION

It is recommended to do further studies with large sample size, using the Hanau articulator combined with a virtual face-bow system, and wax protrusive record as this may help in obtaining more accurate results and it makes the steps simpler.

Conflict of Interest

- There are no conflict of interest regarding the publication of this article.

Funding

- No funding was received for this study.

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