An *In Vivo* Study to Determine a Mathematical Formula to Relate Horizontal Condylar Guidance Angle Derived Clinically and Radiographically

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ABSTRACT

Aim: Present study aims to derive the condylar guidance angle both clinically and radiographically and relate them by a mathematical formula.

Materials and methods: The study was conducted on 22 patients and both the clinically and radiographically derived condylar guidance values are used to derive a mathematical formula. Students *t* test and Pearson correlation test was done to find the difference between sagittal condylar guidance angle between protrusive interocclusal records and panoramic radiographs.

Results: The model of regression for right side was hypothesized and equation obtained was $y = -0.080x + 23.49$, while the model of regression for left side was hypothesized and equation obtained was $y = -0.101x + 25.12$, where y = dependent variable (condylar guidance value obtained by panoramic radiographs) and x = constant variable (condylar guidance value obtained by protrusive interocclusal records). The present study found that on the right side, there was a statistically significant ($p = 0.019$) difference in the mean protrusive interocclusal records (17.04 ± 6.61) and the panoramic radiographs (22.12 ± 7.2) whereas it was not significant ($p = 0.101$) on the left side.

Conclusion: From the observations, it can be concluded that the radiographically obtained condylar guidance angles were higher than the clinically derived angles.

Keywords: Condylar guidance angle, Interocclusal records, Panoramic radiographs, Semi-adjustable articulator, Temporomandibular joint.

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INTRODUCTION

The major goal of prosthetic rehabilitation is restoring the esthetics and functional efficiency of the patient.¹ Whatever may be the treatment that the prosthodontist plans, it should be in harmony with the patient's stomatognathic system. Nature has blessed us with a marvelously dynamic stomatognathic system, which allows us to function and therefore exist.²

One major factor that contributes to its functional efficiency is the occlusion. Occlusion is the static relationship of the teeth and is fundamental to all aspects of dentistry.^{1,2} Occlusion is influenced by factors like anterior and posterior determinants.² Condylar guidance is the posterior determinant of occlusion and this concept is well established in dentistry. Although incisal guidance and cuspal angle are gaining importance as determinants of occlusion,³ condylar guidance cannot be overlooked. Thus, in completely edentulous patients, while attempting to restore the lost occlusion, the importance of condylar guidance should be considered. Condylar guidance is the mandibular guidance generated by the condyle and articular disk traversing the glenoid fossa (GPT-8). It is considered to be a stable factor because it is unalterable in healthy patients.⁴ However, in the case of trauma, pathology, it alters.

In clinical dentistry, it appears to be a common belief that mandibular movements *in vivo* can be reproduced to a large extent with the use of adjustable articulator,⁵ but one factor governing these movements of the adjustable articulator is the sagittal condylar guidance angle (SCGA). The methods used to determine the inclination of the sagittal path of condyles are:⁶

One method is based on the Christensen phenomenon, which consists of employing intraoral protrusive records and then

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calculating the angle in the articulator by programming (Posselt). A graphic method in which the condylar path is recorded on a card by means of a face bow (Gysi technique, McCollum technique) and a radiographic techniques (Panoramic radiographs, Cineradiographs).

Direct interocclusal records are most commonly used because of their simplicity according to Dawson. But many authors have stated that errors can occur because of the technique used in recording and transferring the records from dental arches to an articulator.⁷ By using the graphic method, there is less influence of possible errors⁶ from poorly adapted recording bases. But fixation of the tracing plates or papers during tracing is a probable source of error in this method.

Although radiographic methods like cineradiography and panoramic radiography cause radiation exposure to the patient, they were found to be useful in setting the condylar guidance angle.⁸⁻¹⁰ However, effective may be the techniques existing,

each has its own merits and demerits. A combination of two or more techniques helps in decreasing errors. So, the present *in vivo* study relates the sagittal condylar guidance angle derived clinically using interocclusal records and radiographically using panoramic radiographs using a mathematical equation since mathematical equations are highly effective in comparing biological values.

MATERIALS AND METHODS

Method of Selection of Patients

A total of 22 completely edentulous patients, irrespective of gender, were selected between the age group of 40 years and 70 years from the regular outpatient in Narayana Dental College and Hospital. The patients with good neuromuscular coordination, with no severe systemic problems and temporomandibular joint (TMJ) abnormalities, and those who are willing to participate are included in the study. Informed consent was taken from patients and institutional ethical committee approval was taken. The clinical and radiographic steps were carried out in the Department of Prosthodontics.

Clinical Recording of SCGA

Maxillary and mandibular primary impressions were made with impression compound (Y-Dents) and primary casts were prepared. Special trays were fabricated using self-cure acrylic resin (DPI). Border molding was done and final impressions were made using zinc oxide eugenol paste (DPI) and master casts were obtained. Permanent stable denture bases were fabricated using heat cure acrylic resin (DPI). Occlusal rims were fabricated using hard wax (CAVEX). Orientation jaw relation was recorded using face bow (Hanau spring bow) (Fig. 1) and the maxillary cast was mounted to the articulator (Hanau wide-view). Tentative centric relation record was obtained by using zinc oxide eugenol paste (DPI) by nick and notch method and the mandibular cast was mounted to the articulator. Extraoral height tracers were attached to the occlusal rims. The patients were trained and extraoral gothic arch tracings were recorded. Interocclusal records were obtained using orthocol (Kalabhai, Mumbai) (Fig. 2) at centric and protrusive positions (4–6 mm from centric). Using the centric relation record, the mandibular cast was remounted in the correct centric relation position, and programming of the articulator was done using the protrusive record. On programming, the sagittal condylar guidance angle was obtained on both sides and they were tabulated.

Radiographic Method of Recording SCGA

Orthopantomographs were taken for all the patients during the wax-try in stage, at a pre-determined vertical dimension, using Planmeca radiographic unit in the Department of Oral Medicine and Radiology in Narayana Dental College following the standard protocol of radiographic technique.

Radiographic Tracing

The obtained orthopantomographs were traced using Dolphins software^{11,12} in the Department of Orthodontics, Narayana Dental College. The following landmarks were marked using the software (Figs 3 and 4).

- Orbitale (O): Lowest point on the inferior bony margin of orbit.
- Porion (P): Highest bony point on the upper margin of the external auditory meatus.

Fig. 1: Face bow transfer (lateral view)

- Superior most point of the articular eminence.
- Inferior most point of articular tubercle.
- Using these landmarks, the following planes were obtained.
- Frankfort horizontal plane—plane obtained by joining lowest on the inferior bony margin of orbit (Orbitale) and highest bony point on the upper margin of external auditory meatus (Porion).
- Mean condylar path—obtained by joining superior most point of articular eminence and inferior most point of articular tubercle.

The statistical analysis was done using SPSS statistical analysis software (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA: IBM Corp). Students *t* test was done to find the difference between sagittal condylar guidance angle on the right side and left side in between protrusive interocclusal records and panoramic radiographs. Pearson correlation test was done for comparison between protrusive interocclusal records and panoramic radiographs on the right and left sides.

RESULTS

The angle formed by the intersection of the two planes (FH plane and mean condylar path) gives the sagittal condylar guidance angle. This was obtained on both sides and tabulated (Tables 1, 2, and Figs 5 to 7).

The model of regression for right side was hypothesized and equation obtained was $y = -0.080x + 23.49$, while the model of regression for left side was hypothesized and equation obtained was $y = -0.101x + 25.12$, where y = dependent variable (condylar guidance value obtained by panoramic radiographs) and x = constant variable (condylar guidance value obtained by protrusive interocclusal records). The present study found that on the right side, there was a statistically significant ($p = 0.019$) difference in the mean protrusive interocclusal records (17.04 ± 6.61) and the panoramic radiographs (22.12 ± 7.2) whereas it was not significant ($p = 0.101$) on the left side.

DISCUSSION

If the philosophy of balanced occlusion is accepted as the desirable and professional method of using denture teeth, the condylar path should be determined on the patient and set on the articulator so that the patient's TMJ is in harmony with the occlusion as programmed on the articulator.

Figs 2A and B: Extraoral gothic arch tracings and interocclusal records

Fig. 3: Line diagram interpreting sagittal condylar guidance angle

Fig. 4: Orthopantomograph tracing using Dolphin software

Table 1: Sagittal condylar guidance angle (Mean $\pm$ S.D.) on the right side and left side

Method	No. of subjects	Mean $\pm$ S.D	Std. error	t value	p value
Protrusive interocclusal records right	22	17.04 $\pm$ 6.61	1.41	-2.436	0.019*
Panoramic radiographs right	22	22.12 $\pm$ 7.2	1.53		
Protrusive interocclusal records left	22	19.18 $\pm$ 8.12	1.73	-1.678	0.101
Panoramic radiographs left	22	23.17 $\pm$ 7.66	1.63		

* Statistically significant at p value ≤ 0.05

Table 2: Pearson correlation test for comparison between protrusive interocclusal records and panoramic radiographs on the right and left sides

Method		Pearson correlation	p value
Protrusive interocclusal records right	Panoramic radiographs right	−0.074	0.745
Protrusive interocclusal records right	Panoramic radiographs left	−0.250	0.261
Protrusive interocclusal records left	Panoramic radiographs left	−0.108	0.633
Protrusive interocclusal records left	Panoramic radiographs right	−0.087	0.700
Protrusive interocclusal records right	Protrusive interocclusal records left	0.487*	0.021

*Correlation is significant at p value ≤ 0.05

Recording the condylar guidance angle is a prerequisite for any prosthetic rehabilitation, though it is a clinical challenge. The sagittal condylar path as measured in a living body has a convex S-shaped curvature inferiorly.³ According to Aull,¹³ the sagittal condylar path showed a straight line in only 8% population, and in the remaining 92%, it was a curved path.

Currently, the method in use for recording condylar guidance is a combination of graphic and interocclusal record methods. For the making of interocclusal records, different authors suggested

different materials like irreversible hydrocolloids, zinc-oxide eugenol paste, elastomeric materials, interocclusal waxes, each having its merits and demerits. The reliability of these materials has been questioned in different studies^{7,8,14} This has led to the search for new methods for obtaining SCGA, like the radiographs.^{9,10,15-21}

However, the limitations of the radiographic method are panoramic distortion, head and reference plane orientation,²⁰ and difficulty in distinguishing the articular eminence outline from the

Figs 5A and B: Comparison between condylar guidance values

Fig. 6: Correlation between condylar guidance values between protrusive interocclusal records and panoramic radiographs on the right side. The linear regression equation on right side $y = -0.080x + 23.49$

Fig. 7: Correlation between condylar guidance values between protrusive interocclusal records and panoramic radiographs on the left side. The linear regression equation on left side $y = -0.101x + 25.12$

zygomatic arch. The positions of the two reference lines relative to each other may vary if there is a change in beam direction due to positioning errors.

In the present study, the SCGA values obtained from both methods are tabulated (Table 1) and statistically analyzed. Data analysis showed that the protrusive interocclusal records on the right side were 17.04 ± 6.61 (mean $\pm$ S.D), whereas it was 19.18 ± 8.12 on the left side. Similarly, panoramic radiographic records of the patients were analyzed; data revealed that the panoramic radiographs angle on the right side was 22.12 ± 7.20 and on the left side it was 23.17 ± 7.66 (Table 2). The present study found that on the right side, there was a statistically significant ($p = 0.019$) difference in the mean protrusive interocclusal records (17.04 ± 6.61) and the panoramic radiographs (22.12 ± 7.2) whereas it was not significant ($p = 0.101$) on the left side (Table 1 and Figs 6 and 7).

Pearson correlation was done to obtain a correlation between protrusive interocclusal record and panoramic radiographs on the right and left sides. On the right side, the r value was -0.074 and the p value was 0.745 which indicates condylar guidance angles obtained by protrusive interocclusal records and panoramic radiographs are negatively correlated. On the left side, r value was -0.108 and the p value was 0.633 which indicates condylar

guidance angles obtained by the protrusive interocclusal record and panoramic radiographs are negatively correlated. A simple linear regression analysis was done on the right and left sides which showed that there is a negative best fit line on both sides. The condylar guidance value obtained by the panoramic radiograph increases when the values obtained by protrusive interocclusal records decreases.

The model of regression (obtained by statistical analysis) for the right side was hypothesized and the equation obtained was $y = -0.080x + 23.49$, where y = dependent variable (condylar guidance value obtained by panoramic radiographs) and x = constant variable (condylar guidance value obtained by protrusive interocclusal records). The correlation coefficient was -0.074 on the right side (negative correlation) (Fig. 6).

The model of regression for the left side was hypothesized and the equation obtained was $y = -0.101x + 25.12$, where y = dependent variable (condylar guidance value obtained by panoramic radiographs) and x = constant variable (condylar guidance value obtained by protrusive interocclusal records). The correlation coefficient was -0.108 on the left side (negative correlation).

The present study results were in line with Zamacona et al.,⁶ which stated condylar path inclination is variable on the left and

right sides. A study by Gilboa et al.,⁹ stated panoramic radiographs replicated the articular eminence in dry human skulls with a mean difference of 7° which was similar to the present study.

Similarly, the present study is comparable with Shah et al.,¹⁷ who observed that condylar guidance values by the radiographic method were >1.97° and 3.18° than the protrusive interocclusal method from the right and left sides, respectively. Also coinciding with the present study were results obtained in studies by Shah et al.,¹⁹ Venkateshwaran et al.²⁰

However, results were contrary to the results obtained by Patil et al.²¹ who stated that condylar guidance values did not differ between Hanau H2 and OPG.

Limitations of the present study were the number of subjects which were 22, and there lies a confliction on the stage at which the radiograph should be taken. There was a statistically significant difference between the condylar guidance values obtained during jaw relations, wax try-in, denture insertion, and the radiographs taken at all those stages.¹⁰ The present study did not consider this factor and has taken the angle obtained during the try-in stage as it was proved to be nearer to the radiographic angle. Thus, we suggest further studies to be conducted with increased sample size and taking into consideration the stage at which the radiograph is taken.

CONCLUSION

From the observations, it can be concluded that the radiographically obtained condylar guidance angles were higher than the clinically derived angles. There was a significant correlation between both the angles on the right side rather than on the left side. The probable reasons for the difference between both sides could be the change in the anatomy of the TMJ and also due to variation in direction and magnitude of condylar movements. In cases where taking the clinical records is not possible, radiographs can be taken as an aid in assessing the condylar guidance angle, rather than relying on the average values.

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