Original Article

AN ASSESSMENT OF THE RELATIONSHIP BETWEEN CONDYLAR GUIDANCE AND CUSPAL ANGULATION – AN INVITRO STUDY

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ABSTRACT

This study aims to assess and correlate the existing relationship between cuspal angulation and condylar guidance in natural dentition. 56 Pretreatment samples (lateral Cephalogram and study models) of subjects were included in this study. The Cuspal angulation was measured by 3dimensional technology by scanning the study model. Cuspal angulation is formed by the inclination of the cuspal slope and the line passing through the cusp fossa of a respective tooth. For measuring cuspal angulation, the study model is scanned by an extra-oral scanner (shinning 3d auto scanner). STL image of the study cast was obtained and with the help of haptic device cuspal angulation is measured in a cross-section manner. Condylar guidance was measured on Lateral Cephalogram, as the angle between the line tangential to the posterior slope of articular eminence and Frankfort horizontal plan was obtained. The Statistical analyses were taken using Statistical Package for the Social Sciences SPSS software. The measured values were subjected to a Bivariate Correlation test and evaluated the correlation by the scatter plot test. A p-value more than 0.05 was considered to be statistically non-significant. Bivariate Correlation analysis reveals that Pearson's Correlation coefficient between cuspal angulation and condylar guidance is 0.117 (P= 0.41). There is no statistically significant correlation between factors that are usually changed during orthodontic treatment.

Key words: Orthodontic treatment, Temporomandibular joint disorder, Cuspal angulation, Condylar guidance.

Introduction

The development and harmonious function of the stomato-gnathic system is a complex one. Stomato-gnathic system is a functional unit comprising several structures, like skeletal components (maxilla & mandible), dental arches, associated soft tissue, temporomandibular joints, and masticatory muscles. These structures act in harmony to perform different functional tasks (speech, mastication & deglutition) [1]. Teeth and their related adjacent structure such as tempero-mandibular joint, occlusal plane inclination, cuspal angulation, and curve of spee, their inter-relationship with each other play an important role in the development and maintenance of the stomato-gnathic system.

A smooth functioning of the stomato-gnathic system requires an adaptive development of the associated structures. Occlusal plane inclination and curve of spee are usually changed during orthodontic treatment. Cuspal angulation is mostly under the genetic influence and less influenced by environmental factors. Hence it is logical to assume that cuspal angulation (occlusal form) is the one that most likely influences the other factor in achieving and maintaining the harmonious function of the stomato-gnathic system.

One of the basic functions carried out by the stomato-gnathic system is the collection and grinding of food. Mandibular movements are responsible for grinding the food [2] which is significantly controlled anteriorly by incisal guidance and posteriorly by condylar guidance. Condylar guidance is the angle formed between the slopes of the posterior articular eminence to the Frankfort horizontal plane.

Condylar guidance is significantly affected by the inclination of the articular eminence. The inclination of articular eminence changes rapidly until the completion of deciduous dentition, attaining more or less 45% of its adult value by the age of 2, 70-72% of its growth by the age of 10 years, 90-94% of its growth by the age of 20 years [3]. Condylar guidance is influenced by changes in dental status and function. In the case of infants, the structure of the Tempero-mandibular joint (TMJ) is adapted to neo-natal edentulousness. In childhood, the eruption of teeth, the formation of occlusion, and the growth of the jaw influence and stimulate the development of TMJ. Continuous bone remodeling takes place until the joint reaches its adult condition [4]. The decreasing value of condylar guidance with advancing age is accompanied by changes in the occlusal plane [5]. Cuspal angulation is the angle formed between the functional cuspal slope incline to the line passing through the center fossa of the respective teeth. The relation between incisal guidance

angle and the growth and development of temporomandibular joint has also been recorded [6].

In this study, an effort is made to assess these two factors (condylar guidance and cuspal inclination) and observe how they are interrelated for the normal development and harmonious functioning of the stomato-gnathic system in natural dentition. Since these factors will be altered during orthodontic treatment, a better understanding of their inter-relationship will help us to make successful treatment planning without any post-orthodontic problems such as functional disturbance of temporomandibular joint, post-orthodontic relapse, clenching, attrition of posterior teeth, etc.

Materials and Methods

The study was reviewed and approved by the Institutional Review Board (approval number 197/IHEC/1-19). The 56 Pretreatment samples (lateral Cephalogram and study models) of subjects were included in this study. The study sample size was calculated G*Power version 3.1.9.7 with α err prob= 0.05, Power (1-β err prob) = 0.95. The total sample size is calculated to be 56 with the Actual power = 0.9509895.

Pre-treatment samples were screened to meet the inclusion and exclusion criteria. The inclusion criteria are a Standard Lateral Cephalogram (high-quality image providing sufficient information) and a study model of the age group of 20 to 35 years.

The exclusion criterion includes U1 to NA - less than 4 mm /22°, (To rule out the compensation done by incisal guidance), Subjects having a gingival or periodontal health problem, or having a treatment that would undermine a healthy tooth relationship. Subjects with the apparent loss of tooth structure due to attrition or fracture. Subjects with parafunctional habits and bruxism. Subjects with signs and symptoms of temporomandibular disorders, facial asymmetries, or congenital facial defects. Subjects who have undergone any orthognathic, orthodontic or reconstructive surgery. Subjects with skeletal and dental asymmetry, congenital (Dental anomalies), or maxillofacial defects. Subjects having restorations on more than 2 posterior teeth in each quadrant.

Reference plane and angles
Frankfort Horizontal Plane (*FH plane)(a)*: Frankfort Horizontal plane connects the lowest point of the orbit (orbitalae) and the superior point of the external auditory meatus (porion) **(Figure 1)**.

Condylar Guidance (c) On the Lateral Cephalogram, the angle between the line tangential to the posterior slope of articular eminence(b) and the Frankfort horizontal plan was obtained. Angle between these two planes is measured and denotes the condylar guidance **(Figure 1)**.

Cuspal Angulation: Cuspal angulation is formed by the inclination of cuspal slope and the line pass through the cusp fossa of respective teeth. The distal slope of palatal cusp in Bicuspid, Distal slope of disto buccal and mesio buccal cusp in 1st & 2nd molars are taken in to consideration **(Figure 2)**. Cross- sectionally, angulation of distal slope of functional cusp to the line perpendicular to the long axis of respective teeth were measured in upper arch is considered as the cuspal angulation.

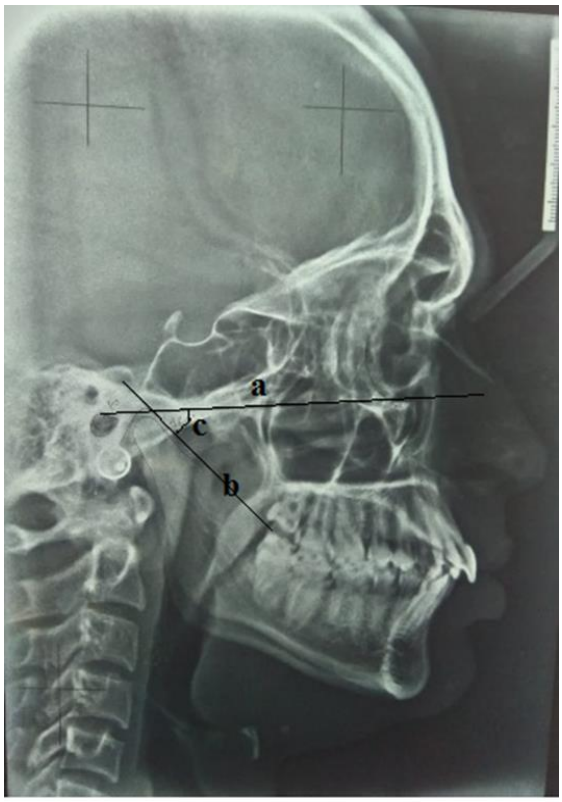

Figure 1. condular guidance
a) FH Plane, b) posterior slope of articular eminence, c) condylar guidance angle

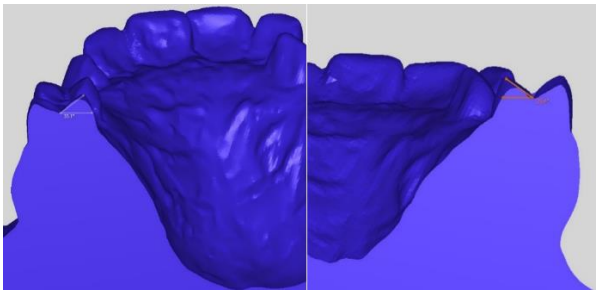

Figure 2. Cuspal angulation.

Results and Discussion

The Statistical analyses were done using Statistical Package for the Social Sciences SPSS software [ver. 22.0; SPSS Inc., Chicago, IL, USA]. The measured values of condylar guidance, Cuspal angulation, were subjected to a

Bivariate Correlation test and evaluated the correlation by a scatter plot test. A p-value of more than 0.05 was considered to be statistically Non- significant **(Table 1)**.

Table 1. Bivariate Correlations: Cuspal Angulation versus Condylar Guidance

Variables compared	Pearson's correlation coefficient (r)	Strength of correlation	Significance (P value)
Cuspal Angulation vs Condylar guidance	0.117	Very weak positive	Non-Significant (0.41)

Bivariate Correlation analysis reveals Pearson's Correlation coefficient between cuspal angulation and occlusal plane -0.117 (P= 0.41). It indicates there is no significant association between these factors.

The average of cuspal angulations of both premolars and molars (1st and 2nd molar) were taken into statistical analysis, and the condylar guidance for each subject was measured on a lateral Cephalogram. Association between the cuspal angulation and condylar guidance was shown in the graph **(Figure 3)**. The correlation between cuspal angulation and condylar guidance was not statistically significant (p=0.41).

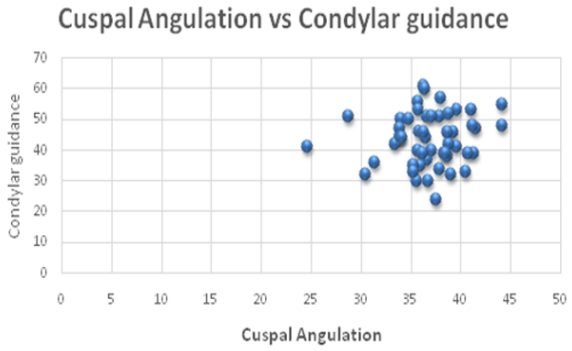

Figure 3. Associat ion between the cuspal angulation andcondylar guidance

Deformity in the facial skeleton leads to malocclusions which can impair digestion and the breakdown of foods. When there is an improper jaw relationship maximal interdigitation of the dentition may not occur leading to compromised kinematics of the mandible and TMJ dysfunction like pain, clicking, and locking of the TMJ. Orthodontic therapy has been considered a primary etiologic factor for TMD [7, 8] Wishney *et al.* [9] evaluated the risk of orthodontic therapy along with their evidence base.The role of orthodontics in treating TMD has always been under confusion. Unfortunately, this paved way for medico-legal issues in several countries. Hence it is necessary to understand the role of orthodontics in TMDs [10, 11]. Yup.AU *et al.* [12] evaluated the prevalence and severity of temporomandibular disorders (TMDs) in prospective orthodontic patients, the presence of TMDs had a significant negative impact on oral health related quality of life.

The relationship between orthodontics and temporomandibular joint disorders is of great interest in the past. Even though literature reveals the negative effect of orthodontics on the stomatognathic system, it is difficult to analyze and examine the variables involved because of its heterogeneity. The methods used to evaluate the diagnostic criteria and analyze the result to define the disease (TMD) have not been standardized. The etiology of temporomandibular joint disorders is multifactorial in nature [13].

The important structures that influence the stomatognathic system are masticatory apparatus such as teeth and its associated structures are the tempero-mandibular joint, the inclination of the occlusal plane, cuspal slope angulation, and the curve of spee. These factors and their inter-relationship play a vital role in the function and maintenance of the stomatognathic system [14]. There are no studies in the Literature comparing the factors that influence the stomatognathic systems which were altered during orthodontic treatment. Hence this study was aimed at assessing and correlating the existing relationship between condylar guidance and cuspal angulation in natural dentition. The present study is an attempt to find the relationship between cuspal angulation and condylar guidance in the existing natural dentition. This study also aimed at providing baseline data to analyze whether these factors are correlated with one another.

Condylar guidance is the mandibular guidance generated by condyle and articular disc traversing the glenoid fossa contour. Literature suggests that the radiographic method can record condylar guidance more accurately. Hence the use of cephalograms, pantomograms, and tomograms for recording condylar guidance was considered the most accepted method. Many studies have revealed a positive correlation between the values obtained from protrusive interocclusal records on the articulator and values of lateral cephalogram tracings more than the panoramic radiograph [15, 16]. Hence lateral cephalograms may be considered a reliable tool for recording the sagittal condylar guidance angle when compared to the clinical method and CBCT. From the Lateral Cephalogram, the angle between the line tangential to the posterior slope of articular eminence and Frankfort horizontal plane are measured as condylar guidance. Chaea *et al.* [17] evaluated the condyle-fossa relationship in adolescents with various skeletal patterns using cone-beam computed tomography. Various techniques were used to measure the condylar guidance by either extraoral or intraoral methods to register the path of the condyle and to adjust the condyle

accordingly. Extraoral methods are generally elucidated and are used in edentulous patients. The most commonly used intraoral methods are interocclusal protrusive wax records, leaf gauges, Lucia jig, and intraoral tracers. However, many authors rely on average values of condylar guidance ranging from 22° to 65°. Centric and eccentric relations of the mandible are recorded by intraoral or positional wax method [18].

The Cuspal angulation was measured from a digital study model (shining 3d auto scanner). Cuspal angulation is formed by the inclination of the cuspal slope and the line passing through the cusp fossa of a respective tooth. STL image of the study model was taken with the help of haptic device measuring the angulation in cross-section. The distal slope of palatal cusp in Bicuspid, Distal slope of disto buccal and mesio buccal cusp in maxillary first and second molars were taken in to consideration. Methods to measure and evaluate the cuspal angulation of premolar and molars in human dentition are 3d imaging technique, photograph metric study, paleoanthropology study and manual technique using putty impression. In 3D imaging technique, cuspal slope angulation is measured by software and the result of this method more precise. The cuspal angulation calculated by photogrammetry method by taking two diagonal snap shot of study cast and merge the photos and measure the cuspal angulation in that images. The Palaeoanthropological studies still depend on descriptive techniques and manual measurements of morphological parameters and is also based on original photogrammetric system as a teeth 3D model acquisition device and run on a set of algorithms for the given tooth parameters estimation. In older days the cuspal angulation measurement were made by manually taking a segmental putty impression and correctly slice the impression at the cusp tip and measured the angle formed from cusp tip to central fossa and a line perpendicular to the long axis of teeth [19].

The result of the study was evaluated by Bivariate Correlation analysis. The analysis revealed that there is no significant correlation between condylar guidance and cuspal angulation. Hence the result of the study proves that changing the cuspal angulation during orthodontic treatment does not influence the stomatognathic system.

Gilboa *et al*. [20] concluded that articular eminence inclination (AEI) usually ranges between 21 and 64 degrees. Koyoumdjisky *et al*. [21] measured the inclination of the anterior wall of the glenoid fossa and provided a mean value of 47.6˚, while Zoghby *et al*. [22], found a mean value of 47.46˚ using the method of mechanical axiography study samples. Hence it has been concluded that the normal value of AEI in adults ranges between 30˚ and 60˚. AEI values smaller than 30˚ have been characterized as shallow, while those greater than 60˚ have been characterized as steep condylar guidance. The results of various studies correspond to this range and are similar to the values recorded in the present study

The results of this retrospective cephalometric study support the '"general" hypothesis that orthodontic treatment is not causative of TMD. The variables specifically addressed in this study were condylar guidance and cuspal angulation in natural dentition. The data from this study are consistent with previous investigations, and provide additional evidence, demonstrating the "passive" relationship between orthodontics and TMD.

The "strength" of this study was all subjects used in this study had no past or present history/ record of TMD before the initiation of the investigation. Therefore conclusion from this study can only be made relative to the actual variables tested (i.e., condylar guidance and cuspal angulation relation in natural dentition) and cannot be generalized to all orthodontic treatment mechanotherapy.

The findings from this study correspond closely, but not exactly, with those previously reported. Direct comparison is difficult due to the difference in factors that were evaluated in previous studies. Recently, a meta-analysis concluded that the data did not indicate that traditional orthodontic treatment increased the prevalence of TM [23].

It was forecast that there is a relationship between condylar guidance and cuspal angulations. Due to the lack of such correlations, the previously derived conclusions become subject to discussion, as they concluded that cuspal angulations were positively correlated with the condylar guidance and incisal guidance while it was negatively correlated with occlusal plane inclination and curve of spee.

The significance of this research is the resultant questioning of the validity of established rules as put forth by clinicians of the various dental specialties, namely the assumption that all factors of balanced occlusion are interrelated mechanically. Perhaps too much emphasis is placed on this theory and insufficient thought is given to the adaptability of the neuro-muscular complex as the compensatory mechanism which affords harmonious utilization of the masticatory apparatus even though certain factors of occlusion are out of "balance."

One of the limitations of the study is retrospective in nature. Prospective studies with larger sample sizes and groups based on the phenotype of malocclusion can provide further insight into this area.

Conclusion

The result reveals a statistically insignificant relationship between condylar guidance and cuspal angulation. The conclusion of this study exists as additional evidence.

The present study concludes that there is no association between condylar guidance and cuspal angulation in the natural untreated dentition. In the future, studies can assess the correlation of the remaining factors such as the curve of spee and occlusal plane inclination in natural dentition.

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Ethics statement: The study was reviewed and approved by the Institutional Review Board (approval number 197/IHEC/1-19).

References

1. Cuccia A, Caradonna C. The relationship between the stomatognathic system and body posture. Clinics. 2009;64(1):61-6.
2. Kijak E, Margielewicz J, Lietz-Kijak D, Wilemska-Kucharzewska K, Kucharzewski M, Śliwiński Z. Model identification of stomatognathic muscle system activity during mastication. Exp Ther Med. 2017;13(1):135-45.
3. Katsavrias EG. Changes in articular eminence inclination during the craniofacial growth period. Angle Orthod. 2002;72(3):258-64.
4. Csadó K, Márton K, Kivovics P. Anatomical changes in the structure of the temporomandibular joint caused by complete edentulousness. Gerodontology. 2012;29(2):111-6. doi:10.1111/j.1741-2358.2011.00498.x
5. Sreelal T, Janardanan K, Nair AS, Nair AS. Age changes in horizontal condylar angle: a clinical and cephalometric study. J Indian Prosthodont Soc. 2013;13(2):108-12. doi:10.1007/s13191-012-0192-z
6. Li Y, Zhou W, Wu Y, Dai H, Zhou J. The relation between incisal guidance angle and the growth and development of temporomandibular joint: a multi-cross-sectional retrospective study. BMC Oral Health. 2021;21(1):1-0.
7. Roberts WE, Stocum DL. Part II: Temporomandibular Joint (TMJ)-Regeneration, Degeneration, and Adaptation. Curr Osteoporos Rep. 2018;16(4):369-79. doi:10.1007/s11914-018-0462-8
8. Sim HY, Kim HS, Jung DU, Lee H, Han YS, Han K, et al. Investigation of the association between orthodontic treatment and temporomandibular joint pain and dysfunction in the South Korean population. Korean J Orthod. 2019;49(3):181-7. doi:10.4041/kjod.2019.49.3.181
9. Wishney M. Potential risks of orthodontic therapy: a critical review and conceptual framework. Aust Dent J. 2017;62 Suppl 1:86-96. doi:10.1111/adj.12486
10. Machado E, Machado P, Cunali PA, Grehs RA. Orthodontics as risk factor for temporomandibular disorders: a systematic review. Dental Press J Orthod. 2010;15(6):e1-10.
11. Jeelani W, Habib A, Ali B, Ahmed M. Effect of Orthodontic Treatment With Straight-Wire Appliance on the Incidence of Temporomandibular Disorders—A 3-Year Cohort Study. J Indian Orthod Soc. 2019;53(4):249-55.
12. Yap AU, Chen C, Wong HC, Yow M, Tan E. Temporomandibular disorders in prospective orthodontic patients: Their association with malocclusion severity and impact on oral health–related quality of life. Angle Orthod. 2021;91(3):377-83.
13. Rendell JK, Norton LA, Gay T. Orthodontic treatment and temporomandibular joint disorders. Am J Orthod Dentofacial Orthop. 1992;101(1):84-7. doi:10.1016/0889-5406(92)70086-P
14. Surendran SV, Hussain S, Bhoominthan S, Nayar S, Jayesh R. Analysis of the curve of Spee and the curve of Wilson in adult Indian population: A three-dimensional measurement study. J Indian Prosthodont Soc. 2016;16(4):335-9. doi:10.4103/0972-4052.191290
15. Galagali G, Kalekhan SM, Nidawani P, Naik J, Behera S. Comparative analysis of sagittal condylar guidance by protrusive interocclusal records with panoramic and lateral cephalogram radiographs in dentulous population: A clinico-radiographic study. J Indian Prosthodont Soc. 2016;16(2):148-53.
16. Marchiori EC, Garcia RR, Moreira RW. Importance of occlusal plane reproduction on the semi-adjustable articulator in planning maxillary impactions for orthognathic surgery. Oral Maxillofac Surg. 2013;17(2):109-14. doi:10.1007/s10006-012-0353-6
17. Chae JM, Park JH, Tai K, Mizutani K, Uzuka S, Miyashita W, et al. Evaluation of condyle-fossa relationships in adolescents with various skeletal patterns using cone-beam computed tomography. Angle Orthod. 2020;90(2):224-32. doi:10.2319/052919-369.1
18. Jerath S, Rani S, Kumar M, Agarwal SK, Kumar S, Rathore A. Clinico-radiographic comparative evaluation of horizontal condylar guidance angle by interocclusal wax record, cbct, and gothic arch tracing method- an in vivo study. Int J Recent Sci Res. 2019;10(07):33715-20. doi:10.24327/ijrsr.2019.1007.3732
19. Gaboutchian AV, Knyaz VA, Leybova NA. Measurements of Cuspal Slope Inclination Angles in Palaeoanthropological Applications. ISPRS - Int Arch Photogramm, Remote Sens Spat Inf Sci. 2017;52W4:185-91.

20. Gilboa I, Cardash HS, Kaffe I, Gross MD. Condylar guidance: correlation between articular morphology and panoramic radiographic images in dry human skulls. J Prosthet Dent. 2008;99(6):477-82.
21. Koyoumdjisky E. The correlation of the inclined planes of the articular surface of the glenoid fossa with the cuspal and palatal slopes of the teeth. J Dent Res. 1956;35(6):890-901.
22. Zoghby AE, Re JP, Perez C. Functional harmony between the sagittal condylar path inclination and the anterior guidance inclination. J Stomat Occ Med. 2009;2(3):131-6.
23. Kim MR, Graber TM, Viana MA. Orthodontics and temporomandibular disorder: A meta-analysis. Am J Orthod Dentofacial Orthop. 2002;121(5):438-46.