Original Article

Comparative evaluation of the depth of curve of Spee between individuals with normal dentition and individuals with occlusal wear using conventional and digital software analysis techniques: An *in vivo* study

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Abstract

Objectives: The objective of this study is to evaluate and compare the depth of curve of Spee in normal dentitions and dentitions with occlusal wear using conventional and digital software techniques.

Materials and Methods: A total of 70 healthy human subjects were selected for this study in an age group of 20–50 years. Group A includes the stone models (dental casts) of 35 individuals with healthy (nonattrited) dentition. Group B includes stone models of 35 individuals with occlusal wear (generalized attrited) dentition. Two methods were used for measuring the curve of Spee, i.e., conventional method and three-dimensional digital analysis method.

Results: Depth of the curve of Spee between these two groups was statistically the same. The Digital software analysis (Method II) gives more accurate readings when compared with the Conventional (Method I) of measuring the depth of the curve of Spee.

Conclusion: Depth of curve of Spee is maintained through the life. There is no statistical difference in depth of curve of Spee between the two groups and digital method give more accurate measurements.

Keywords: Curve of Spee, digital analysis technique, occlusal wear

INTRODUCTION

Human dentition, i.e., the teeth and their supporting tissues is a mutually protected, organized arrangement of maxillary and mandibular teeth to serve the functional and esthetic need of the body. Occlusion is a dynamic biological relationship of components of the masticatory system that control tooth contact during function and dysfunction.[1] Occlusal curvature is a naturally occurring phenomenon in the human dentition. This curvature was termed the curve of Spee, by Ferdinand Graf von Spee a German anatomist.[2] This anteroposterior curve, or curve of Spee, was defined as the anatomical curve established by the occlusal alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of

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the premolar and molar teeth, continuing through the anterior border of the mandibular ramus and ending at the anterior aspect of the mandibular condyle (Glossary of Prosthodontics terms 1994).[3] The curve of Spee is designed to permit protrusive disocclusion of the posterior teeth by the combination of anterior guidance and condylar guidance. It is essential to know the standard value of occlusal curvature for examination and treatment of occlusal disharmony.[4]

According to Kitasako *et al.*, advanced wear progression predominantly observed on incisal/occlusal surfaces of tooth, early dentin exposure was observed in the middle age group (40–49 years).[5] The age group of 20–50 was selected as we wanted the whole range from a healthy nonattrited sets of teeth to the cases where attrition had exposed the dentin. Occlusal wear of teeth due to attrition is the result of friction by functional and parafunctional activities. Frictional tooth wear alters the existing occlusal plane introducing deflective occlusal interferences.[6] As age progresses, changes in the inclination of the occlusal surface of the tooth with wear have been described, and this wear may be due to physiologic wear or pathologic wear. If the curve of Spee is not restored in the worn dentition, then prosthetic teeth will not be aligned along it. It is essential in all aspects of restorative dentistry to maintain occlusal harmony and comfort of the patient.[7] It is essential to know the standard value of occlusal curvature for examination and treatment of occlusal disharmony. This could be used as basis for clinical guideline for full mouth rehabilitation in removable or fixed prosthodontics. Therefore, the objective of this study is to compare and evaluate the depth of curve of Spee between individuals with normal dentition and individuals with occlusal wear using conventional and digital software analysis techniques.

MATERIALS AND METHODS

1. Perforated metal stock impression tray
2. Vacuum mixing machine (Whip mix, USA) (MODEL NO: 5KH39QN9629DX SERIAL NO: MO2050167)
3. Vibrator (Confident 158)
4. Base former
5. Rigid measuring scale
6. Digital Vernier Caliper
7. CAD-CAM scanner (3M ESPE LAVATM Scan ST)
8. Computer installed with coral draw software.

Method
Subject selection criteria
A total of 70 healthy human subjects were selected for this study in an age group of 20–50 years. On the basis of

a detailed questionnaire and verification through clinical examination, two study groups (A and B) were formed.

Group A includes the stone models (dental casts) of 35 individuals with healthy (nonattrited) dentition.

Group B includes stone models of 35 individuals with occlusal wear (generalized attrited) dentition. All the individuals were selected based on following inclusion and exclusion criteria as recommended by Ferrario *et al.*[8]

Inclusion criteria
1. Complete permanent dentition including 2nd molar (minimum of 28 teeth) with bilateral Angle's class I permanent molar and canine relationship with a horizontal and vertical overlap ranging from 2 to 4 mm.

Exclusion criteria
1. Moderate or severe clinical mandibular disorders (no temporomandibular joint [TMJ] sounds, tenderness of TMJ and masticatory muscles on palpation, and painful limitations of mandibular movements)
2. Extensive restorations, cast restorations, or cuspal coverage
3. Previous or current orthodontic treatment
4. Anterior or lateral crossbite
5. Pathological periodontal conditions.

After selecting the individuals, the curve of Spee was measured on the mandibular models. Two techniques were used to measure the depth of the curve of Spee in age groups of 20–50 years.
I. Conventional technique
II. Digital software analysis technique.

Index for categorizing subjects with occlusal wear
Subjects with occlusal wear are rated clinically with the help of tooth wear index given by Smith and Knight 1984 [Table 1].[9] The score of 2 or above 2 will be considered as occlusal wear groups.

Impression making
The individuals were seated on the dental chair in a relaxed and upright position. A sterilized perforated stock metal tray of appropriate size was selected to make an irreversible hydrocolloid impression of the mandibular arch. Manufacturer recommended water powder ratio was followed and mixing was initiated by adding measured quantity of water to clean flexible rubber bowl. This was followed by the addition of correctly proportioned powder. The irreversible hydrocolloid impression material (Tropicalgin, Zhermack, Mumbai, Maharashtra,

India) was uniformly loaded on to the selected impression tray [Figure 1]. The loaded tray was carried to the mouth and centered over the teeth. Uniform pressure was applied to obtain an accurate impression of mandibular arch.

After the material is set, the impression was removed with a sudden jerk from the mouth and inspected for defects under good lighting before it is rinsed. Excess unsupported alginate was removed with a sharp knife. For patients with thin serous saliva impressions were rinsed with cold water to remove any saliva or blood. But for a patient with thick, ropy saliva a thin layer of dental stone powder was sprinkled onto the surface of the impression which adheres to saliva and acts as a disclosing agent. When impression was placed under running tap water, the saliva can be seen and can be removed by light brushing with wet camel's hairbrush. Impressions were immersed in 2% gluteraldehyde for 5 min to disinfect and pouring was done by mixing the Type III dental stone (Kalabhai Karson Private Ltd., Mumbai, Maharashtra, India) [Figure 2] under the vaccum mixing machine to obtain a cast. The cast was retrieved and base was poured using the specific base former (Dentsply) for all the models to achieve uniform height of the cast.

Conventional method

Stone models were undertaken for manual measurements, followed by which the rigid plate (measuring scale) was positioned in such a way that it touches the cusp tip of mandibular canine and the distobuccal cusp tips of mandibular second molar[10] [Figure 2]. Perpendicular distances were measured between the mesiobuccal cusp tips of the mandibular first molar and rigid plate [Figure 1]. In all the 70 models, 35 stones models of each group underwent for measurement of the depth of the curve of Spee on both the sides and mean of it was taken for statistical analysis.

Digital software analysis technique
Scanning of models

All the casts were scanned under three-dimensional Scanner using LAVA Design 7 software (3M ESPE, Banglore, India ltd) [Figure 3]. In all the 70 models, 35 stone models of each group were scanned to obtain three-dimensional digital models. In the scanning machine, the cast was secured on the cast holder in such a way that the optical laser light was perpendicular on the cast. Scanning of stone models was done to obtain digital models [Figure 4].

Digital software analysis

The depth of the curve of Spee was analyzed by CORAL DRAW software with 3 coordinates (x, y, z) in 3 different
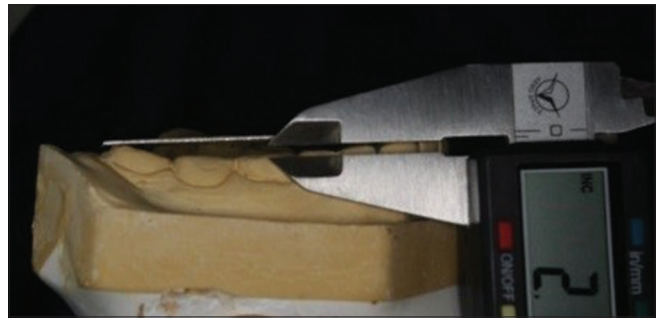

Figure 1: Conventional (manual) method of measurement of depth of curve of Spee

Figure 2: Stone model obtained for measurement

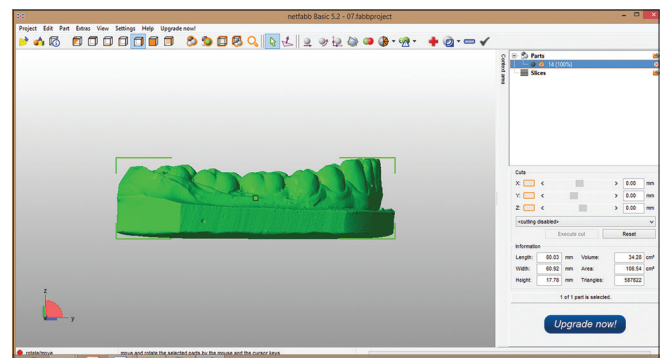**Figure 3:** Three-dimensional Scanner using LAVA design 7 software

Figure 4: Scanned model obtained on computer

planes. These models were captured in right and left view and the captured image was transferred to the coral draw software, and with the help of this software, a line was drawn from the mandibular canine cusp tip to distobuccal cusp tip of second molar and a perpendicular distance was measured from the mesiobuccal cusp tip of first molar to the line drawn from the canine cusp tip to distobuccal cusp tip of second molar [Figure 5].

Statistical analysis

Independent '*t*'-test was done for statistical difference.

RESULTS

A. i. Depth of the curve of Spee in normal individuals by digital software analysis method (1.86 mm) was significantly higher than the conventional method (1.47 mm) (*P* < 0.05) [Table 2 and Graph 1]

   ii. Depth of the curve of Spee in individuals with occlusal wear measured by digital software analysis method (1.91 mm) was significantly higher than the conventional method (1.48 mm) (*P* < 0.05) [Table 3 and Graph 2]

B. Depth of the curve of Spee measured by digital method in individuals with normal dentition and individuals with occlusal wear dentition. No significant difference was found between the occlusal wear (1.91 mm) and normal individuals (1.86 mm) (*P* > 0.05) [Table 4 and Graph 3]

C. Depth of the curve of Spee measured by conventional method in individuals with normal dentition and occlusal wear dentition. No significant difference was found between the occlusal wear (1.48 mm) and individuals with normal teeth (1.47 mm) (*P* > 0.05) [Table 5 and Graph 4].

DISCUSSION

Occlusion is the foundation for clinical success in fixed, removable, and implant supported prosthodontic treatment.[11-15] The dynamic interface of the maxillary and mandibular occlusal surfaces has been studied for more than three centuries.

There is no consensus on the measurement of the curve of Spee because some authors have used incisal edge of central incisor whereas others have used canine tip for the curve of Spee measurement.[8,16,17] According to Veli *et al.* the deepest point of the COS was found at the mesiobuccal cusp of the first molar for all malocclusion groups.[18] Garcia[19] reported that the deepest point in most patients at the mesiobuccal cusp of the permanent first molar. On the other hand, Koyama[20] reported the deepest point at the second premolar area.
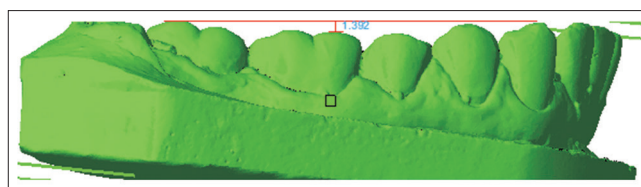

Figure 5: Digital method of measurement of depth of curve of Spee

Table 1: Tooth wear index (Smith and Knight)

Score	Criteria
0	No loss of enamel surface characteristics
1	Loss of enamel surface characteristics
2	Buccal, lingual, and occlusal loss of enamel, exposing dentine for <1/3 of the surface; incisal loss of enamel; minimal dentine exposure
3	Buccal, lingual, and occlusal loss of enamel, exposing dentine for >1/3 of the surface; incisal loss of enamel; substantial loss of dentine
4	Buccal, lingual, and occlusal complete loss of enamel, pulp exposure or exposure of secondary dentine; incisal pulp exposure or exposure of secondary dentine

Table 2: Curve of Spee in healthy (normal) dentition individuals by two techniques (methods)

Method	n	Mean (mm)	S.D	S.E.M	(Independent sample *t* test)
Conventional method	35	1.47	0.337	0.095	0.0001 (sig)
Digital software analysis method	35	1.86	0.431	0.096	

Table 3: Curve of Spee in individuals with occlusal wear (attrited) dentition by two techniques (methods)

Method	n	Mean (mm)	S.D	S.E.M	(Independent sample *t* test)
Conventional method	35	1.48	0.547	0.097	0.0137 (sig)
Digital software analysis method	35	1.91	0.811	0.096	

**Table 4: Curve of Spee in normal dentition and occlusal wear (attrited) dentition measured by digital method**

Method	n	Mean (mm)	S.D	S.E.M	(Independent sample *t* test)
Normal teeth	35	1.86	0.431	0.074	0.7733 (N.S.)
Occlusal wear teeth	35	1.91	0.811	0.139	

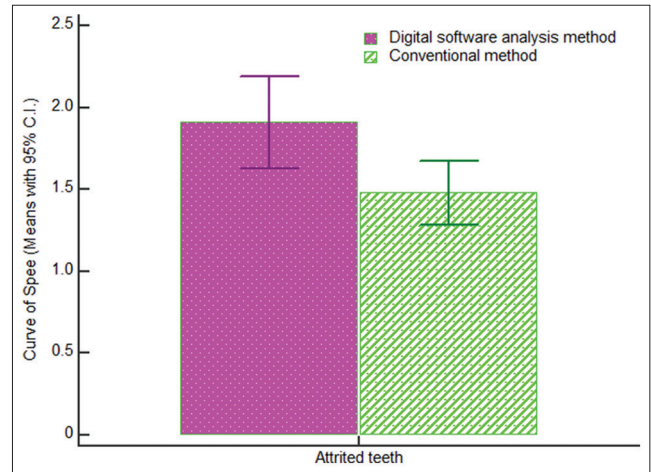**Table 5: Curve of Spee of normal dentition and occlusal wear (attrited) dentition measured by conventional method**

Method	n	Mean (mm)	S.D	S.E.M	(Independent sample *t* test)
Normal teeth	35	1.47	0.337	0.057	0.9763 (N.S.)
Occlusal wear teeth	35	1.48	0.547	0.095	

Baldridge *et al.* used the perpendicular distances on both sides. Bishara *et al.* used the average of the sum of the perpendicular distances to each cusp tip.[21] Sondhi *et al.* used the sum of the perpendiculars.[22] Braun *et al.* and Braun and Schmidt used the sum of the maximum depth on both sides.[23,24]
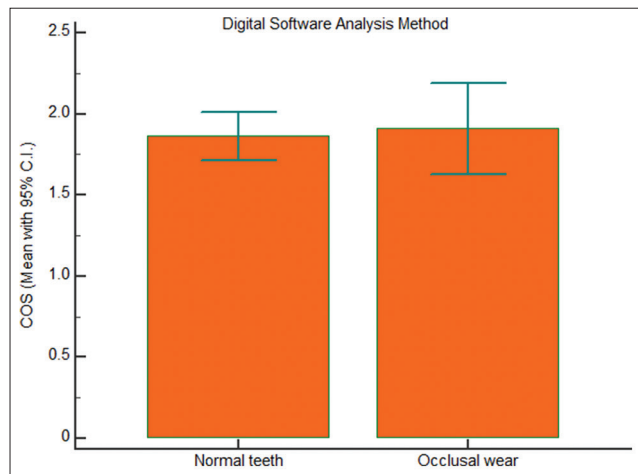
Xu *et al.* examined the differences in the Spee's curve between the maxillary and mandibular arches and stated
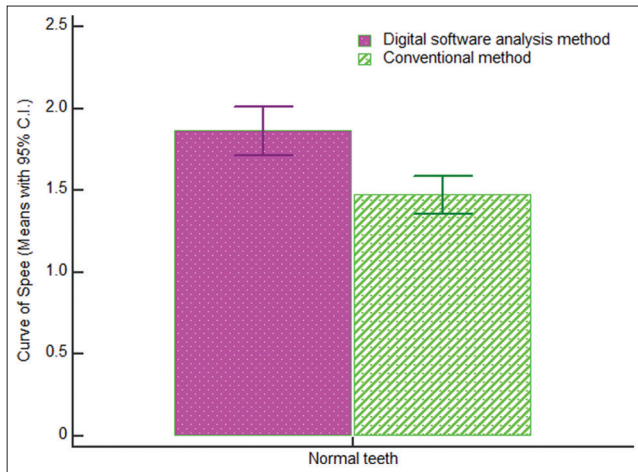
Graph 1: Curve of Spee (mean with 95% confidence interval) in normal dentition measured by two different techniques

Graph 2: Curve of Spee (mean with 95% confidence interval) with occlusal wear (attrited) dentition measured by two different techniques

Graph 3: Curve of Spee (mean with 95% confidence interval) in normal dentition and occlusal wear (attrited) dentition measured by digital method
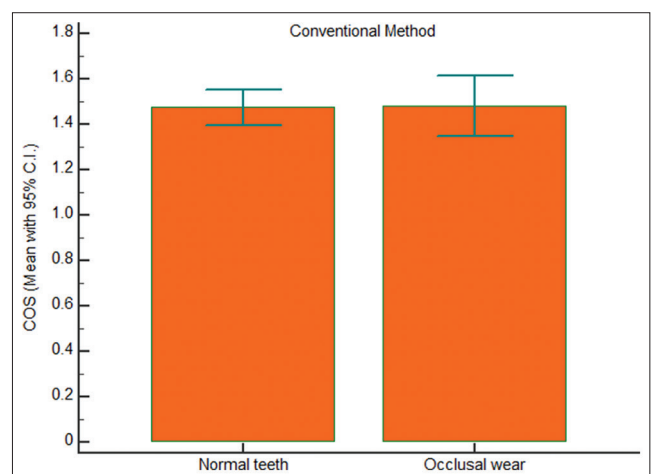
Graph 4: Curve of Spee (mean with 95% confidence interval) in normal dentition and dentition with occlusal wear measured by conventional method

that the depth of the curve of Spee was approximately 1.6 mm (men, 1.6 mm and women, 1.5 mm) in the maxillary arch and 1.9 mm (men, 1.9 mm and women, 1.8 mm) in the mandibular arch.[10] Marshall *et al.* have shown in their study that there are no significant differences in maximum depth of curve of Spee between either the right or left sides of the mandibular arch or the sexes.[25]

The depth of the curve of Spee is a critical point for prosthodontic treatment protocols. The depth of the curve of Spee has a significant role in maintenance and function of occlusion. There is a significant change in the curve of Spee with age, and it is used as a reference for prosthodontic rehabilitation. The clinician should be aware of that how much amount of depth of curve of Spee has to be restored during full mouth rehabilitation. Therefore, measurement of the curve of Spee is one of the important factors in determining the success in treatment.

Failure to do so may lead to interferences along the mandibular movement which will jeopardize the health of the stomatognathic system. In the present study, the depth of the curve of Spee in normal individuals and individuals with attrited dentition measured by digital software analysis method was significantly higher than the conventional method [Tables 2 and 3]. This concurs with the findings of Xu *et al.*[10] that the depth of the curve of Spee obtained by digital method was same. The result of the present study was in disagreement with Sengupta *et al.*[7] who stated that there is a resultant reversing of the curve of Spee and also Brown, Knott, Bjork, and De Kock reported that there is a natural tendency for the depth of the curve of Spee to decrease with age.

Another finding in our study was that the depth of the curve of Spee measured by digital method among the

individuals with normal teeth up to third molar was significantly higher than that measured up to second molar [Table 6]. Although clinically, there is difference in the depth of the curve of Spee between healthy dentition and individuals with occlusal worn (attrited) dentition, statistically there is no significant difference was found. Therefore, result says that the depth of the curve of Spee is maintained throughout the life and also the attrition pattern is such that the maximum attrition pattern is seen in the first molar teeth and thus maintaining the curve of Spee.

As the patients grow older, clinicians should be aware that the occlusal adjustments with age have gradually altered the curve of Spee of youth toward a more favourable individual occlusal curvature. Thus, if the curve of Spee is not maintained in these dentitions during full mouth rehabilitation, it may lead to interferences along the mandibular movements which will jeopardize the health of the masticatory system.[26]

The curve of Spee permits total posterior disclusion on mandibular protrusion provided anterior tooth guidance is proper. The curve of Spee may be pathologically altered in situations resulting from rotation, tipping, or extrusion of teeth. Restoration of the dentition to such an altered occlusal plane can introduce posterior protrusive interferences.[27,28] Such interference has been shown to cause abnormal activity in mandibular elevator muscles, especially the masseter and temporalis muscles. Furthermore, it has been suggested that excursive interferences may result in wear, fracture of restorations, and TMJ dysfunction.[29] A highly significant correlation is demonstrated between the forward inclination of the superficial masseter muscle and the forward tilt of molar teeth in the sagittal plane, conforming to the posterior end of the curve of Spee.[19,30,31] This correlation between the muscle of mastication and forward tilt of molar teeth in sagittal plane (curve of Spee) supports the theory that the curve of Spee has a biomechanical function during food processing by increasing the crush/shear ratio between the posterior teeth and the efficiency of occlusal forces during mastication.

Analysis of the curve of Spee in sagittal plane will guide the dentists in determining the development of the occlusion. The maxillary and mandibular curves of Spee could be used as a reference for prosthetic rehabilitation and orthodontic

reconstruction. Management of the sagittal organization of the teeth is a critical determinant of the stability of complete dentures[32] and may play a role in the fabrication of implant-supported prosthesis.

CONCLUSION

The understanding of curve of Spee in the field of prosthodontics is very important, as a Prosthodontist has to deal with it virtually in every patient he treats. Occlusion starts its journey from the deciduous dentition and travels taking variable forms influenced by various factors till the edentulous condition of an individual. Curve of Spee is one of the important factors in rehabilitation procedure to achieve optimal result. The present study shows that depth of curve of Spee is maintained through the life. There is no statistical difference in depth of curve of Spee between the two groups and digital method give more accurate measurements. Further study has to carry out for measurement of the curve of Spee in complex cases such as deep bite, open bite which will help us to restore stable occlusion. Although long-term clinical study is also required to analyze the estimated curve of Spee in full mouth rehabilitation cases.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Albert S, Donald CC. Health and dysfunction of the stomatognathic system. Occlusal Correction and Principles and the Practice. Chicago, Illinois: Quintessence Publishing Co., Inc.; 1988. p. 17-26.
2. The displacement path of the lower jaw at the skull. Arch Anat Physiol 1890;16:285-94.
3. Ash M. Wheeler's Dental Anatomy, Physiology and Occlusion. 6th ed. Philadelphia: W.B. Saunders; 1984.
4. 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;16:335-9.
5. Kitasako Y, Sasaki Y, Takagaki T, Sadr A, Tagami J. Erosive tooth wear among different tooth types and surfaces in Japanese adults 15 to 89 years old. Oral Health Prev Dent 2017;15:357-64.
6. Thirumurthy VR, Bindhoo YA, Jacob SJ, Kurien A, Limson KS, Vidhiyasagar P, *et al*. Diagnosis and management of occlusal wear: A case report. J Indian Prosthodont Soc 2013;13:366-72.
7. Sengupta A, Whittaker DK, Barber G, Rogers J, Musgrave JH. The effects of dental wear on third molar eruption and on the curve of spee in human archaeological dentitions. Arch Oral Biol 1999;44:925-34.
8. Ferrario VF, Sforza C, Miani A Jr., Colombo A, Tartaglia G. Mathematical definition of the curve of spee in permanent healthy dentitions in man. Arch Oral Biol 1992;37:691-4.
9. Smith BG, Knight JK. An index for measuring the wear of teeth. Br Dent J 1984;156:435-8.

Table 6: curve of spee in normal dentition measured upto second molar and third molar teeth by digital method

Method	*n*	Mean (mm)	S.D	S.E.M	(Independent sample *t* test)
Upto second molar	15	1.89	0.450	0.101	<0.0001 (sig)
Upto third molar	15	2.93	0.735	0.164	

10. Xu H, Suzuki T, Muronoi M, Ooya K. An evaluation of the curve of spee in the maxilla and mandible of human permanent healthy dentitions. J Prosthet Dent 2004;92:536-9.

11. Keshvad A, Winstanley RB. Comparison of the replicability of routinely used centric relation registration techniques. J Prosthodont 2003;12:90-101.

12. Clayton JA. A pantographic reproducibility index for use in diagnosing temporomandibular joint dysfunction: A report on research. J Prosthet Dent 1985;54:827-31.

13. Obrez A, Türp JC. The effect of musculoskeletal facial pain on registration of maxillomandibular relationships and treatment planning: A synthesis of the literature. J Prosthet Dent 1998;79:439-45.

14. Linsen SS, Stark H, Samai A. The influence of different registration techniques on condyle displacement and electromyographic activity in stomatognathically healthy subjects: A prospective study. J Prosthet Dent 2012;107:47-54.

15. Obrez A, Stohler CS. Jaw muscle pain and its effect on gothic arch tracings. J Prosthet Dent 1996;75:393-8.

16. Spee FG, Beidenbach MA, Hotz M, Hitchcock HP. The gliding path of the mandible along the skull. J Am Dent Assoc 1980;100:670-5.

17. Ferrario VF, Sforza C, Miani A Jr., Tartaglia G. Mathematical definition of the shape of dental arches in human permanent healthy dentitions. Eur J Orthod 1994;16:287-94.

18. Veli I, Ozturk MA, Uysal T. Development of the curve of spee in class II subdivision malocclusion: A longitudinal study. Eur J Orthod 2015;37:412-7.

19. Garcia R. Leveling the curve of spee: A new prediction formula. J Charles H Tweed Int Found 1985;13:65-72.

20. Koyama T. A comparative analysis of the curve of spee (lateral aspect) before and after orthodontic treatment – With particular reference to overbite patients. J Nihon Univ Sch Dent 1979;21:25-34.

21. Bishara SE, Jakobsen JR, Treder JE, Stasi MJ. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood. A longitudinal study. Am J Orthod Dentofacial Orthop 1989;95:46-59.

22. Sondhi A, Cleall JF, BeGole EA. Dimensional changes in the dental arches of orthodontically treated cases. Am J Orthod 1980;77:60-74.

23. Braun S, Hnat WP, Johnson BE. The curve of spee revisited. Am J Orthod Dentofacial Orthop 1996;110:206-10.

24. Braun ML, Schmidt WG. A cephalometric appraisal of the curve of spee in class I and class II, division 1 occlusions for males and females. Am J Orthod 1956;42:255-78.

25. Marshall SD, Caspersen M, Hardinger RR, Franciscus RG, Aquilino SA, Southard TE, *et al*. Development of the curve of spee. Am J Orthod Dentofacial Orthop 2008;134:344-52.

26. Mohan M, D'Souza M, Kamath G, Parolia A. Comparative evaluation of the curve of spee in two age groups and its relation to posterior teeth disclusion. Indian J Dent Res 2011;22:179.

27. Osborn JW. Relationship between the mandibular condyle and the occlusal plane during hominid evolution: Some of its effects on jaw mechanics. Am J Phys Anthropol 1987;73:193-207.

28. Shillinburg HT, Hobo S, Whitsett LD, Brackett S. Fundamentals of Fixed Prosthodontics. 3rd ed. Chicago: Quintessence; 1997. p. 85-6.

29. Williamson EH, Lundquist DO. Anterior guidance: Its effect on electromyographic activity of the temporal and masseter muscles. J Prosthet Dent 1983;49:816-23.

30. Lynch CD, McConnell RJ. Prosthodontic management of the curve of spee: Use of the broadrick flag. J Prosthet Dent 2002;87:593-7.

31. Woods M. A reassessment of space requirements for lower arch leveling. J Clin Orthod 1986;20:770-8.

32. Farella M, Michelotti A, van Eijden TM, Martina R. The curve of spee and craniofacial morphology: A multiple regression analysis. Eur J Oral Sci 2002;110:277-81.