ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2020; 6(1): 183-188

www.oraljournal.com
Received: 26-11-2019
Accepted: 29-12-2019

Ausma Jan
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Rabindra S Nayak
Professor and Head Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Kavya BR
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Suresh S Nair
Senior Lecturer, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Srishti Galav
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Rachana Chopra
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Corresponding Author:
Ausma Jan
Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India

Correlation between curve of spee and various dental and skeletal cephalometric parameters. A radiological study

Ausma Jan, Rabindra S Nayak, Kavya BR, Suresh S Nair, Srishti Galav and Rachana Chopra

Abstract
The aim of this study was to correlate Curve of Spee (COS) with various dental and skeletal cephalometric parameters. The study comprised of 110 lateral cephalograms and orthodontic study models. The subjects were divided into 5 groups on the basis of ANB angle and Angle's molar relation. A statistically significant correlation was found between Angle's molar relation and COS. A statistically significant linear positive relationship of COS with Jarabak Ratio and L7 to MP distance was seen. The direction of the relationship was negative in relation to L1 to MP angle. It was concluded that depth of COS was greater in Group IIb > Group IIa >GroupIIc >Group I >Group III. COS increases with an increase in Jarabak's ratio and L7 to MP distance and decreases with increase with L1 to MP angle.

Keywords: Curve of Spee, Angles molar relation, Jarabak ratio

1. Introduction
Curve of Spee (COS) is defined as the line on a cylinder which is tangent to incisal edges of lower anteriors, occlusal surface of lower second molar and anterior border of condyle [1]. Ferdinand Graf von Spee a German embryologist (1855-1937) was the first to describe the Curve of Spee in 1890. He used skulls with abraded teeth to define the line of occlusion. This line on a cylinder which is tangent to incisal edges of lower anteriors, occlusal surface of lower second molar and anterior border of condyle Von Spee located the center of this cylinder in the mid orbital plane having radius of 6.5 to 7.0 cm. [1, 2] Clinically COS is measured from distal marginal ridges of the most posterior teeth in the arch to the incisal edges of the anteriors [3].
Andrews [4] described six keys to normal occlusion. The curve of Spee is the sixth key to occlusion. He found that the curve of Spee ranges from flat to mild in subjects with proper occlusion and hence best static occlusion can be achieved with flat occlusal plane.
The understanding of how the curve of Spee develops is limited in literature. Some have suggested that its development probably results from a combination of many factors which include growth of orofacial structures, eruption of teeth and development of neuromuscular system [5, 6].It has been mentioned that the mandibular sagittal & vertical position relative to cranium is related to curve of Spee, which is present in various forms in mammals. In humans an increased curve of Spee is often seen in brachycephalic facial patterns and associated with short mandibular bodies [7, 8, 9].
Several theories have been proposed to explain the presence of COS in natural dentition. It has been mentioned that an imbalance between the anterior and posterior components of occlusal force can lead to supra eruption of lower incisors, infra eruption of premolars, mesial inclination of lower molars. This altered condition requires special skills for the practitioner. Thorough knowledge would be useful of how and when this this COS develops so that it will help us in treatment planning [10, 11].
Levelling the curve of Spee represents a routine procedure in orthodontic practice [12] and more pronounced the curve is, additional space is required to flatten the dentition [13]. The assessment of depth of curve of Spee represents a critical point for orthodontic diagnostic & treatment protocol [14].

Therefore the present study is aimed at evaluating correlation between Curve of Spee and various skeletal and dental cephalometric parameters.

2. Materials and Method

The present cross-sectional study was done in M.R. Ambedkar Dental College and hospital Bangalore. The study material comprising of lateral cephalograms and orthodontic study models were taken from the archives of the Department of Orthodontics and the patients reporting to the department routinely for treatment.

Signed informed consent was obtained from parents/patients prior to entry into the study and protocol was appropriately approved by the Institutional Ethics committee.

2.1 Inclusion Criteria

1. Patients who have all their teeth erupted except for 3rd molars
2. No history of previous orthodontic treatment
3. No history of severe facial trauma, severe craniofacial disorders such as cleft palate.
4. Age range – 14 to 26 years.

2.12 Exclusion Criteria

1. Patients with cast restoration
2. Patients with severe attrition
3. Anterior or lateral cross bite

2.13 The grouping of individuals done in the study was as follows:

GROUP I (30 subjects): Skeletal Class I malocclusion, ANB angle $0\text{-}4^0$

GROUP II(60 subjects): Skeletal Class II malocclusion ANB angle $\geq 4^0$

GROUP III (20 subjects): Skeletal Class III malocclusion ANB angle $\leq 0^0$

Classification of Group II into 3 subgroups ANB angle
Group IIa (20 subjects): Angle's Class II Div. 1 malocclusion.
Group IIb (20 subjects): Angle's Class II Div. 2 malocclusion
Group IIc (20 subjects): Angles Class II Subdivision malocclusion

2.14 Material Used for the Study

- Lateral cephalograms
- KODAK 8000C digital panoramic and cephalometric system.
- Films for all the lateral cephalograms will be of the size 8x10"and magnification will be around 1.3x.The software used for this will be KODAK software.
- 0.3mm graphite pencil
- 0.7mm acetate sheet of 8x10'' size
- High quality alginate impression & well-polished diagnostic study models
- Ney surveyor
- Vernier caliper.

2.15 Methodology

The maximum depth of the curve of Spee were measured as the maximum perpendicular distances between the buccal cusp tips of the mandibular teeth and a measurement plane described by central incisors and the distal cusp tip of the most posterior tooth in the mandibular arch. A digital caliper was mounted on a Ney surveyor. Dental casts were levelled to a plane defined by the distobuccal cusps of the right and left most posterior tooth and the most central point on the more erupted central incisor. The right and left maximum depths were recorded and averaged to arrive at the average maximum depth of each subject which is considered as curve of Spee[3]. Molar relation was measured from maxillary and mandibular models in occlusion according to Angle's classification. The following skeletal and dental parameters were taken.

Skeletal parameters:

1. **Jarabak ratio [30]:** Ratio between posterior facial height (S-Go) to anterior facial height (N-Me)
2. **Lower anterior facial height. (LAFH):** Linear distance between ANS to Menton (Me).
3. **Upper anterior facial height to lower anterior facial height ratio:** Ratio between Nasion to ANS and ANS to Menton.
4. Dental Parameters:
5. **Molar relation:** Angles molar relation
6. **Anterior mandibular dental height.(L1 to MP):** Perpendicular distance measured from incisal edge of mandibular central incisor to mandibular plane (Go-Gn)
7. **Posterior mandibular dental height. (L7 to MP):** Perpendicular distance measured from mesiobuccal cusp tip of mandibular 2nd molar to mandibular plane. (Go-Gn).
8. **Incisor mandibular plane angle. (L1 to MP angle):** Angle formed between long axis of mandibular central incisor and mandibular plane.

3. Statistical Analysis

Statistical package for Social Sciences [SPSS] for windows version 22.2 Released 2013.Armonk, NY:IBM Corp., was used to perform statistical analyses. The data was subjected to descriptive analysis for mean, range, standard deviation and 95% confidence interval. One way ANOVA test followed by Tukey's HSD post hoc Analysis was used to compare the mean values of skeletal and dental parameters based on different types of curve of Spee. Level of significance (P-value) was set at $P<0.05$.Spearman's correlation coefficient was used to compare the correlation of COS with other parameters.

4. Results

On comparison one way ANOVA showed statistically significant difference between molar relation and curve of Spee. (P= 0.001). Tukey's post hoc analysis shows statistically significant difference between Angle's Class I, Class II div 1, Class II div 2, Class II subdivision and Class III molar relationship variables among curve of Spee. (P= 0.001). Spearman's correlation shows that the Curve of Spee shows statistically significant linear positive relationship with Jarabak Ratio (P = 0.001; rho=+0.390) and L7 to MP (P = 0.016; rho = +0.228). This indicates Jarabak Ratio and L7 to MP values increases as COS increases. The direction of the relationship is negative in relation to L1 to MP angle (P = 0.001; rho = -0.461), this indicates L1 to MP angle tends to increase in opposite directions with COS value.

4.1 Tables

Table 1: Tukeys Post-hoc analysis

Tukey HSD						
(I) Groups	**(J) Groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Class I Molar relation	Class II div 1	-1.64667*	0.09	0.001*	-1.8965	-1.3969
	Class II div 2	-2.93167*	0.09	0.001*	-3.1815	-2.6819
	Class II subdivision	-1.14667*	0.09	0.001*	-1.3965	-0.8969
	Class III	1.36833*	0.09	0.001*	1.1185	1.6181
Class II div 1	Class I Molar relation	1.64667*	0.09	0.001*	1.3969	1.8965
	Class II div 2	-1.28500*	0.09859	0.001*	-1.5587	-1.0113
	Class II subdivision	.50000*	0.09859	0.001*	0.2263	0.7737
	Class III	3.01500*	0.09859	0.001*	2.7413	3.2887
Class II div 2	Class I Molar relation	2.93167*	0.09	0.001*	2.6819	3.1815
	Class II div 1	1.28500*	0.09859	0.001*	1.0113	1.5587
	Class II subdivision	1.78500*	0.09859	0.001*	1.5113	2.0587
	Class III	4.30000*	0.09859	0.001*	4.0263	4.5737
Class II Div subdivision	Class I Molar relation	1.14667*	0.09	0.001*	0.8969	1.3965
	Class II div 1	-.50000*	0.09859	0.001*	-0.7737	-0.2263
	Class II div 2	-1.78500*	0.09859	0.001*	-2.0587	-1.5113
	Class III	2.51500*	0.09859	0.001*	2.2413	2.7887
Class III	Class I Molar relation	-1.36833*	0.09	0.001*	-1.6181	-1.1185
	Class II div 1	-3.01500*	0.09859	0.001*	-3.2887	-2.7413
	Class II div 2	-4.30000*	0.09859	0.001*	-4.5737	-4.0263
	Class II subdivision	-2.51500*	0.09859	0.001*	-2.7887	-2.2413
* The mean difference is significant at the 0.05 level.						

Table 2: Descriptive statistics

Groups		**Jarabak Ratio**	**UFH /LFH**	**ANS to Me**	**L1 to MP**	**L7 to MP**	**L1 to MP angle**	**COS**
Class I Molar relation	N	30	30	30	30	30	29	30
	Mean	61.83	6.27	61.90	37.50	29.17	95.76	2.25
	Std. Deviation	1.86	20.72	1.12	1.38	1.09	3.19	0.42
Class II div 1	N	20	20	20	20	20	20	20
	Mean	61.60	0.82	60.65	37.10	29.60	95.75	3.93
	Std. Deviation	1.50	0.02	1.79	1.29	0.75	3.16	0.21
Class II div 2	N	20	20	20	20	20	20	20
	Mean	71.50	4.77	61.30	37.55	29.80	86.45	5.19
	Std. Deviation	2.80	17.71	1.13	1.10	0.70	2.74	0.21
Class II Subdivision	N	20	20	20	20	20	20	20
	Mean	62.10	0.82	61.75	37.45	29.90	95.60	3.40
	Std. Deviation	1.89	0.01	1.25	1.54	0.72	3.20	0.21
Class III	N	20	20	20	20	20	20	20
	Mean	62.15	0.82	60.55	37.70	29.45	96.45	0.89
	Std. Deviation	1.46	0.01	1.43	1.45	0.51	2.06	0.35
Total	N	110	110	110	110	110	109	110
	Mean	63.65	3.02	61.29	37.46	29.55	94.15	3.05
	Std. Deviation	4.18	13.23	1.44	1.35	0.84	4.67	1.46

Table 3: Spearman's Correlation between Curve of spee with other parameters

		Jarabak Ratio	**UFH / LFH**	**ANS to Me**	**L1 to MP**	**L7 to MP**	**L1 to MP angle**
COS	Correlation Coefficient	**.390****	-0.071	0.016	-0.073	.228*	-.461**
	Sig. (2-tailed)	**0.001**	0.464	0.87	0.448	0.016	0.001
	N	110	110	110	110	110	109
** Correlation is significant at the 0.01 level (2-tailed).							
* Correlation is significant at the 0.05 level (2-tailed).							

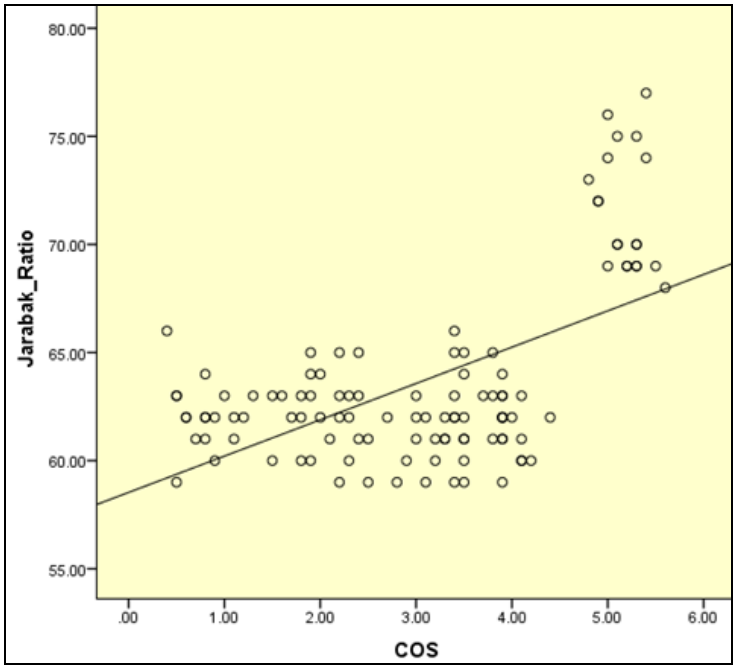

Fig 1: Correlation of COS with Jarabak ratio

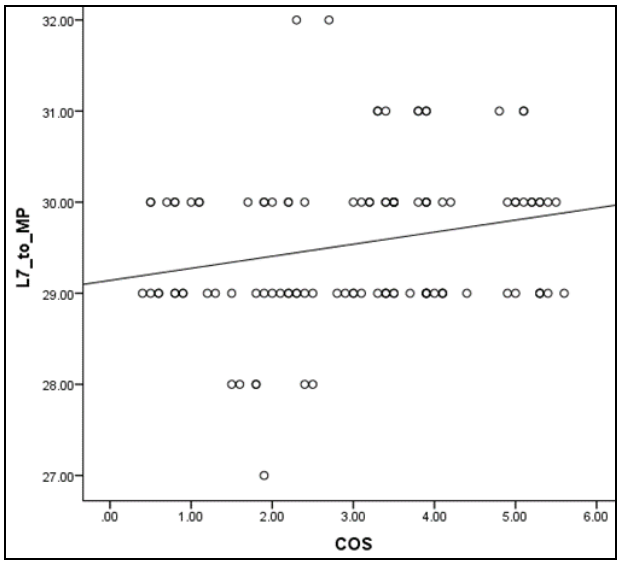

Fig 2: Correlation of COS with L7 to MP distance

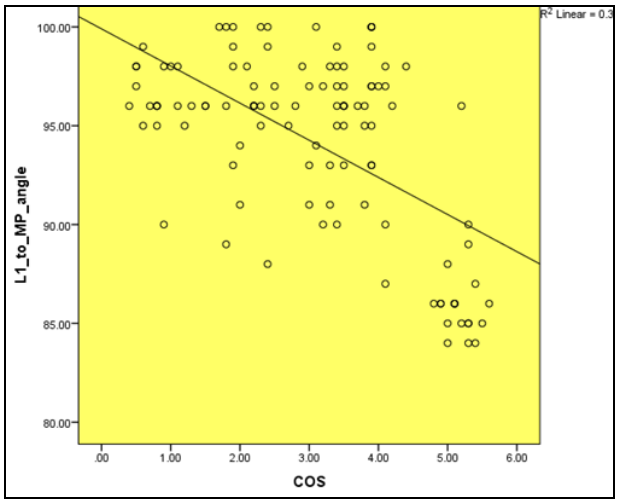

Fig 3: Correlation of COS with L1 MP angle

Fig 4: Curve of Spee measurement by Marshall's method

5. Discussion

The main significance of COS is its role in chewing and mastication; so its evaluation is must for proper diagnosis and treatment planning [15]. The assessment of relationship of COS with dentoskeletal morphology is essential to understand the influence of multiple factors that lead to variation in the depth of Curve of Spee [16]

It has been suggested that COS remains stable from deciduous dentition to adulthood. It is also suggested that homogenous dental wear could be the reason for the maintenance of COS in adulthood [17]. Because of this, adolescents and young adults within the age range of 14-26 years were included in the study.

Lack of sexual dimorphism in the depth of the COS has been reported in the literature so no attempt was made to divide the sample according to gender [18, 19]. The present study aimed to find out whether COS has any correlation with vertical skeletal parameters and dental parameters like molar relation, vertical eruption of mandibular anterior and posterior teeth and inclination of mandibular central incisor with mandibular plane.

There is little consensus in the literature concerning measurement of the depth the COS. Some authors [20] used the perpendicular distances on both sides, while another [21] used the average of the sum of the perpendicular distances to each cusp tip. Some researchers used the sum of the maximum depth on both sides [22, 23]. In the present study, a reference line was used from the incisal edge of lower central incisors to the distal cusp of last erupted molar. Then the perpendicular distance from the deepest cusp tip was measured on the both right and left sides and the mean value was taken into consideration [24].

To eliminate the subjective error due to the cumbersome nature of the manual method such as divider with scale used earlier in the COS measurement, Marshall's method using a Ney surveyor and digital caliper was used [3]. This not only enhanced the accuracy of the results by reducing the least count of measurements but also improved the reliability and reproducibility of values obtained.

In the present study the COS was measured from all the 110 mandibular models by Marshall's method [3]. Molar relation was measured from maxillary and mandibular models in occlusion. The cephalograms were manually traced on lead acetate paper (0.003 inches thickness) with 0.3mm lead pencil. Cephalometric parameters were evaluated.

In the present study, measurement and comparison of the depth of COS in different malocclusion groups (based on ANB angle and molar relation) was done. It showed statistically significant differences among various malocclusion groups. The depth of COS was more in Class II div 2 subjects (group IIb), followed by Class II div. 1 subjects (group IIa) > Class II subdivision (group IIc) >Class I subjects (group I) > and least depth was seen in Class III subjects (group III). Other studies also reported similar results, suggesting that the COS in the mandibular arch is influenced by the anteroposterior position of mandible [25]. This is in accordance with the previous studies that state that the radius of the COS is shorter in those with Class II malocclusion [26]. According to previous literature, patients with Class II malocclusion had a significantly deeper COS than those with Class I malocclusion [27]. However other studies also reported similar depths of the COS for those with Class I and Class II malocclusion [28]. The reason for increased depth of COS in Class II malocclusion could be due to supraeruption of lower incisors [29].

Jarabak ratio [30]: The present study showed statistically significant linear positive relationship with Jarabak Ratio (P = 0.001; rho=+0.390). Previous literature also reported that COS is greater is short face subjects compared to long face subjects which could be ascribed to their different occlusal forces, with short face subjects exhibiting higher forces [17].

Lower 7 to mandibular plane (MP): The present study showed statistically significant and positive correlation between COS and L7 to MP (P = 0.016; rho = +0.228). It may be due to differential vertical eruption. This is in accordance with previous study which also found a statistically significant and positive correlation of COS an L7 to MP distance [24].

L1 to MP angle: In the present study it showed a statistically significant and negative correlation with COS P = 0.001; rho = -0.461).This is in accordance with previous literature which states that levelling of COS causes an increase in arch circumference and proclination of lower incisors [31, 32]. It has been reported that incisor flaring might be predominantly associated to the mechanics of levelling the COS and not necessarily due to disparity in arch circumference [33]. Another study has reported that there were no statistically differences in inclinations of the upper and lower incisors and lower anterior crowding between the Spee groups [27].

There was not any statistically significant correlation of the COS with UFH/LFH, ANS to Me and L1 to MP Linear distance in the present study.

6. Conclusion: Curve of Spee has rightly been regarded as a compensatory curve because this arc defines the compensation in the alignment of dentition in the true sense. Its wide spectrum roles and its contributing factors have long been a subject of focus and discussion, yet this phenomenon remains explained partially. The more the topic is explored, the greater is the scope for further research. COS showed statistically significant linear positive relationship with Jarabak Ratio, and L7 to MP (P = 0.016; rho = + 0.228). This indicates Jarabak Ratio and L7 to MP values increases as COS increases. The direction of the relationship is negative in relation to L1 to MP angle (P = 0.001; rho = -0.461), this indicates L1 to MP angle tends to increase in opposite directions with COS value. Other parameters like UFH/LFH, ANS to Me and L1 to MP linear distance didn't show any statistically significant correlation with COS. The limitation of the present study was its cross-sectional design. Further studies with longitudinal design would be beneficial to better understand its correlation with various factors. The errors in using intersection of points in case of double images and 2-dimensional characteristics of conventional lateral cephalograms were other limitations. Therefore future studies should evaluate the relationship with 3D computerized tomography.

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