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Correlation Between the Curve of Spee and Vertical Divergence in Skeletal Class III Patients

Abstract

Objective: The purpose of this retrospective study was to determine if there is a correlation between the depth of the Curve of Spee (COS) and the mandibular plane angle in individuals with a Class III skeletal relationship.
Materials and Methods: A patient population of 60 Class III skeletal patients was divided into three groups of 20 based on skeletal divergence (Hypodivergent, Normodivergent, Hyperdivergent). For each patient a cephalometric radiograph was traced, and initial intra-oral models were digitized and measured for depth of COS. All measurements were compiled and a statistical analysis consisting of a one-way ANOVA and Pierson Correlation analysis were completed to determine the correlation between the COS and all cephalometric measurements including mandibular plane angle.
Results: The COS was deepest in the normodivergent group (2.09mm) followed by the hypodivergent group (1.63mm) and the hyperdivergent group had the shallowest COS (1.33mm). One-way ANOVA and Tukey's post hoc tests indicated the COS in the hyperdivergent group was significantly smaller than the normodivergent group ($p=0.024$), however the difference was not correlated based on the Pierson Correlation analysis. When all measurements were combined, Pierson Correlation revealed a positive correlation between COS and overbite ($p=.0018$).
Conclusion: There is no correlation between depth of COS and skeletal divergence in Class III skeletal patients. There is a correlation between depth of COS and overbite in skeletal Class III patients in that a deep COS corresponded to a deeper overbite.

Introduction

In 1890 Ferdinand Graf Spee first described the curve that eventually took his name. In viewing the skull in profile, he noticed the occlusal surfaces of the mandibular teeth follow an upward concave curve on a circumferential arc that shares the same radius as the anterior surface of the condyle[1]. That initial observation has been upheld and modified over the last century by numerous studies, textbooks and researchers and is known today as the Curve of Spee (COS). Today the COS is understood to extend from the buccal cusp tips of the mandibular posterior teeth to the incisal edges of the lower incisors[2]. The function of the COS is not fully understood, however, there are several theories. Spee postulated that the curvature increased masticatory surface area and reduced lever affects. Lynch claimed that it allowed posterior disocclusion on mandibular protrusion.[3] Several studies proposed that it increases the crush/shear ratio and overall efficiency of chewing[4, 5].

Leveling the COS is often a key objective of orthodontic treatment. In Larry Andrew's study of normal occlusion, he noted that an ideal plane of occlusion is flat or has a slight COS. He suggested that a flat or slightly over corrected COS be a goal of orthodontic treatment as the COS tends to deepen with age and post pubescent growth[6]. However, leveling of the COS requires additional space, which clinically manifests in proclined teeth and an increase in arch length and circumference [7]. Several studies have attempted to quantify the amount of arch length or circumference increase that results from leveling the COS. These estimates range from 1 mm of COS leveling equivalent to 1 mm of arch circumference increase to complex linear equations that calculate the depth of the curve to a resultant arch length increase[8-10]. This increased

demand for arch length and circumference in deep COS patients is amplified by additional treatment complexities such as skeletal and dental discrepancies in antero-posterior (AP), vertical and transverse planes.

Several studies have investigated a relationship between the three classes of AP dental malocclusion and the depth of the COS. Sayar, et al. noted that COS was deepest in Class II malocclusions and flattest in Class III dental malocclusions[11]. These findings were supported by Veli[12]. Results were mixed, however, for studies evaluating the relationship between COS and AP skeletal relationships. Cheon found a negative correlation between COS and ANB and positive correlation between COS and SNB[13]. Ortholieb found that the COS in Class III skeletal individuals was deeper than in Class II skeletal individuals[14]. Farella found no correlation between COS and ANB[15]. Studies have also evaluated relationships between COS and various vertical dental and skeletal characteristics. Multiple studies concur that a deep COS has been correlated with increased overbite[5, 16]. Results for skeletal divergence were mixed. Kumari found no significant correlation between FMA and COS, but did find a significant negative correlation between Steiners MPA (SN-Go-Gn) and COS[5]. Halimi found no significant correlation between COS and skeletal divergence[17]. Finally, Farella determined that the COS was more pronounced in hypodivergent subjects and less pronounced in hyperdivergent subjects[15]

To date, no studies have directly studied the relationship between COS, Class III skeletal malocclusions and various vertical skeletal growth patterns. The purpose of this study was to investigate the relationship in the depth of the COS in Class III skeletal relationships between hypo, normo and hyperdivergent mandibular plane angles in this patient population. The hypothesis is that hypodivergent Class III skeletal patients will exhibit a deeper COS than normodivergent or hyperdivergent Class III patients.

Materials and Methods

The material for this retrospective study was obtained from the Tri-Service Orthodontic Residency Program (TORP) patient population and records database. The records for the present investigation were selected for individuals of whom the following exclusion criteria were met:

1. A complete permanent dentition (including or excluding third molars)
2. A skeletal Class III relationship (ANB less than 0 degrees)
3. No history of previous orthodontic treatment (determined by review of patient record)
4. Absence of periodontal disease
5. Dental casts available and stored in database
6. Panoramic and lateral cephalometric radiographs available
7. No gross condylar asymmetry

An initial search of Class III patients from the TORP database yielded an initial patient pool of 297 patients. A search was then conducted to divide this record pool into three groups based on mandibular plane angle. The first group had hypodivergent mandibular plane angles (FMA less than 21 degrees). The second group had normodivergent mandibular plane angles (FMA between 21 and 28 degrees). The third group had hyperdivergent mandibular plane angles (FMA greater than 28 degrees). 20 records were selected at random from each of these three groups to form a study population of 60 patients.

For each patient, a traditional cephalogram was used or a reconstructed lateral cephalogram was created from the existing Cone Beam Computed Tomography (CBCT) volume (Dolphin Imaging, 11.95 Premium, Patterson Dental, Chatsworth, CA). The lateral cephalogram was traced, and the following

measurements were made: SNA, SNB, ANB, A-N perpendicular, Pogonion-N perpendicular, SN-MP, FMA, U1-NA, U1-SN, L1-NB, L1-MP.

Next, dental casts for each patient were scanned and digitized (R2000, 3Shape a/S, Copenhagen, Denmark). The digitized 3-dimenstional casts were measured and analyzed using the scanner's software (Orthoanalyzer, 3Shape A/S, Copenhagen, Denmark). All traditional or reconstructed cephalometric tracings and digital cast measurements were completed by a single rater.

The COS was measured following the method previously applied by Rozzi[18]. The mandibular occlusal plane was established by selecting three points: the middle of the distal marginal ridge of the mandibular second molar on each side, and an anterior point created at the midpoint of the incisal edge of the central incisors (Figure 1). Any discrepancy in vertical position of the incisal edges of the central incisors was resolved by selecting a point halfway between the two edges. The depth of each cusp tip to this occlusal reference plane was measured. From these values, the deepest cusp measurement for both the left and right side was recorded (Figure 2). These two values (left and right COS) were averaged for each patient and this value was used for the COS depth.

Statistical Analysis

The data were analyzed and descriptive statistics along with standard deviation values were calculated for all variables in each subgroup. A one-way ANOVA analysis was run to test if any divergence group had a significantly larger COS than another and a Pierson Correlation analysis was run to determine if there was a correlation between depth of COS and the specified cephalometric measurements. Intra-rater reliability was accomplished by retracing 20 randomly selected lateral cephalometric radiographs at least two weeks after initial tracing. 20 randomly selected casts were also remeasured for depth of COS at least two weeks after initial measurement.

Results

The study population consisted of 60 individuals composed of 17 females and 43 males. The average age was 23.5 years old ranging from 11.9-42 years old. Intra-rater reliability was determined by following guidelines published by Koo et al[19]. The lowest intraclass correlation coefficient for any measured variable was 0.91 for A-Nperp which corresponds to the level of excellent intra-rater reliability for all the variables measured.

Table 1 shows the average depth of COS for each group studied. The normodivergent group had the deepest COS (2.09mm) followed by the hypodivergent group (1.63mm), while the hyperdivergent group had the shallowest COS (1.33mm). A one-way ANOVA and Tukey's post hoc test indicated that the COS in the hyperdivergent group was significantly smaller than the normodivergent group ($p=0.024$).

Table 2 shows the results of the correlation analysis relating COS to measured variables in three groups based on skeletal divergence. The hypodivergent group showed a significant negative correlation between COS and U1-NA ($p=0.002$) as well as L1-MP ($p=0.015$). No other groups had any significant correlations with COS. When the groups were combined, an aggregate correlation analysis in Table 3 shows a positive correlation between COS and overbite ($p=0.002$).

Discussion

The data from this study indicates that there is no correlation between the depth of the COS and the mandibular plan angle in Class III skeletal relationships. The hypothesis that hypodivergent Class III skeletal subjects would exhibit a deeper COS than normodivergent or hyperdivergent Class III subjects was found to be false. In fact, normodivergent subjects were found to have a deeper COS than both hypodivergent and hyperdivergent subjects, although that difference was not statistically significant between normodivergent and hypodivergent individuals. Although

normodivergent subjects had a significantly deeper COS than hyperdivergent subjects, the Pierson correlation analysis revealed no correlation between COS and FMA or SN-MP. These findings are consistent with findings from Halimi and Kumari[5, 17]. However, Shannon et al found a significant negative correlation between COS depth and mandibular plane angle[20]. These mixed results among studies may be due to differing protocols in measuring the COS. Orholieb's study created a curve of best fit that followed the occlusal surfaces of the mandibular teeth and measured the COS in terms of a radius. Other studies measured COS similar to this study but varied in the points selected to form the mandibular occlusal plane. Some used the canine instead of the central incisors and some used the distal marginal ridge of the second molars instead of the distal buccal cusp of the second molars. Due to the limited number of studies in this area, additional research with similar protocols could clarify results.

When looking at other craniofacial measurements, the hypodivergent group showed a significant negative correlation between COS and upper incisor antero-posterior position (U1-NA). It also had a significant negative correlation between COS and lower incisor proclination (L1-MP). These findings were supported by Kumari et al[5]. Baydas, however, found no significant correlations between maxillary or mandibular incisor positions and COS[16].

When all groups were combined there was a strong correlation between COS and overbite. This result is supported by numerous studies that all noted increased overbite with increased COS depth[5, 12, 16, 17]. It is interesting to note that when the data was separated into respective skeletal divergence groups there was no significant correlation between COS depth and overbite. This may be due to the fact that the smaller sample size could be more sensitive to significantly larger or smaller outlying values.

Although this study focused specifically on subjects with a Class III skeletal relationship, it is interesting to note that there was no correlation between the severity of Class III and COS depth. Kakade et al found significant positive correlations between COS depth and ANB and SNB[21]. Mujib and Bantham had similar findings[22, 23]. The lack of correlation in this study is most likely due to the small range of SNA values characteristic of skeletal Class III relationships, however a follow-on study that included Class I and Class II skeletal relationships could shed greater light on the correlation between COS depth and ANB.

Several factors may have contributed to the contradictory results as compared with other studies. One factor could be the inclusion of both reconstructed lateral cephalometric radiographs from CBCT and traditional lateral cephalometric radiographs. The slight differences in the machines used and the double image effects of traditional lateral cephalometric radiographs could have skewed the data resulting from their measurements. Future studies using only images reconstructed from CBCT should be part of the inclusion criteria. Another factor could be the cross-sectional retrospective nature of the study. Longitudinal studies could also provide greater insight into how the COS changes through time in relation to skeletal and dental relationships.

Conclusion

There is no correlation between depth of COS and skeletal divergence in Class III skeletal subjects. There is a positive correlation between depth of COS and overbite.

Acknowledgements

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Table 1

Group		COS
Hypodivergent	Mean	1.63
	SD	0.54
	Range	0.59-2.3
Normodivergent	Mean	2.09
	SD	0.93
	Range	0.51-3.44
Hyperdivergent	Mean	1.33
	SD	1.01
	Range	-0.2-3.3

Table 2

Group		SNA	SNB	ANB	A-N Perp	B-N Perp	Pog-N Perp	SN-MP	FMA	U1-NA	U1-SN	L1-NB	L1-MP	COS Avg	Overbite	Overjet
Hypodivergent	**Mean**	**84.08**	**86.73**	**-2.65**	**-0.35**	**3.84**	**6.55**	**24.28**	**16.13**	**7.82**	**114.96**	**4.21**	**90.5**	**1.63**	**2.06**	**1.36**
	SD	**4.64**	**4.43**	**1.91**	**3.08**	**4.74**	**4.83**	**4.43**	**3.03**	**2.1**	**6.02**	**2.63**	**7**	**0.54**	**1.76**	**2.61**
	P Value	**0.175**	**0.274**	**0.472**	**0.190**	**0.318**	**0.450**	**0.544**	**0.976**	**0.002**	**0.060**	**0.422**	**0.014**		**0.1653**	**0.4198**
	Pearson Correlation	**0.315**	**0.256**	**0.170**	**0.305**	**0.234**	**0.178**	**-0.144**	**-0.007**	**-0.647**	**-0.427**	**-0.189**	**-0.537**		**0.322**	**-0.191**
Normodivergent	**Mean**	**79.86**	**82.58**	**-2.71**	**-2.8**	**-0.08**	**1.01**	**33.65**	**24.43**	**8.56**	**109.58**	**8.85**	**84.73**	**2.09**	**2.25**	**1.61**
	SD	**3.17**	**3.64**	**2.51**	**3.95**	**7.42**	**7.47**	**2.8**	**1.82**	**3.01**	**6.66**	**19.2**	**6.93**	**0.93**	**1.98**	**3.5**
	P Value	**0.065**	**0.188**	**0.735**	**0.115**	**0.238**	**0.257**	**0.883**	**0.791**	**0.259**	**0.221**	**0.549**	**0.058**		**0.1365**	**0.3945**
	Pearson Correlation	**-0.419**	**-0.306**	**-0.080**	**-0.363**	**-0.276**	**-0.265**	**-0.034**	**0.063**	**-0.264**	**-0.285**	**0.142**	**-0.430**		**0.344**	**0.2014**
Hyperdivergent	**Mean**	**80.54**	**82.36**	**-1.83**	**-3.86**	**-3.43**	**-3.62**	**39.13**	**31.37**	**8.68**	**109.28**	**5.72**	**82.27**	**1.33**	**0.48**	**0.89**
	SD	**3.69**	**3.69**	**1.76**	**2.86**	**5.74**	**6.51**	**2.93**	**2.06**	**3.77**	**8.3**	**3.13**	**7.62**	**1.01**	**2.04**	**2.61**
	P Value	**0.933**	**0.790**	**0.445**	**0.472**	**0.912**	**0.508**	**0.991**	**0.127**	**0.268**	**0.784**	**0.398**	**0.872**		**0.1807**	**0.1062**

Group		SNA	SNB	ANB	A-N Perp	B-N Perp	Pog-N Perp	SN-MP	FMA	U1-NA	U1-SN	L1-NB	L1-MP	COS Avg	Overbite	Overjet
COS Average	Mean	81.49	83.88	-2.39	-2.335	0.11	1.313	32.35	23.973	8.35	111.27	6.258	85.83	1.69	1.595	1.2885
	SD	5.35	5.375	2.325	4.475	7.05	7.475	7.975	7	3.85	8.375	3.425	10.8	0.12	2.892	3.655
	P Value	0.599	0.618	0.989	0.959	0.975	0.735	0.490	0.290	0.633	0.302	0.294	0.133		0.001	0.112
	Pearson Correlation	-0.069	-0.066	0.001	-0.006	-0.004	-0.044	-0.091	-0.139	-0.063	-0.136	0.13	-0.197		0.398	0.20909
	Pearson Correlation	0.020	-0.065	0.186	0.175	0.026	-0.161	-0.002	-0.362	0.267	0.067	0.205	0.039		0.3206	0.3823

Table 3

Figure 1

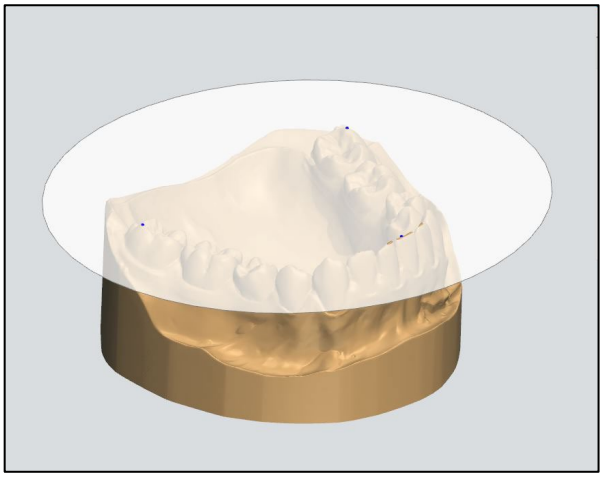

Figure 2