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

Abstract

Objective: The purpose of this study was to build off separate findings from previous studies; specifically that the COS is deeper in Class II skeletal malocclusions or in hypodivergent skeletal patterns. The hypothesis is hypodivergent skeletal patterns will exhibit a greater COS and there is a correlation between the mandibular plane angle and the depth of the COS in Class II patients.
Materials and Methods: This was a retrospective study. 60 total Class II patients were divided into 3 equal groups based on their vertical skeletal divergence (hypodivergent, normodivergent, and hyperdivergent). From this population, measurements were recorded from their reconstructed lateral cephalograms and pre-treatment study models. The data was aggregated and analyzed with Pearson Correlation Coefficient, one-way ANOVA, and descriptive statistics.
Results: The COS average was deepest in hypodivergent patients (2.43mm), and shallowest in hyperdivergent (2.05mm), however the differences, calculated by One-way ANOVA, were not significant ($P > 0.05$). The correlation analysis found that when looking at COS to all the variables aggregated, there was a small negative correlation to L1-NB ($p < 0.05$), and a large positive correlation to both overbite and overjet ($P= 0$)
Conclusion: The COS was not correlated to the mandibular plane angle in skeletal Class II patients. Secondly, the COS was positively correlated to both overjet and overbite; as both overbite and overjet increased, the COS also increased. Finally, the COS was negatively correlated to L1-NB; the more retrusive the lower incisors, the deeper the COS.

Introduction

The natural occlusal curvature of the mandibular teeth, when viewed from the sagittal, was first described by Ferdinand Graf von Spee[1]. The curve of Spee (COS) is not unique to humans, being found in other mammals and fossil records of early human ancestors; however, our understanding of its importance and the purpose behind its development is minimal. During adolescence in the mixed dentition, the COS depth increases when the mandibular incisors and first molars erupt before the maxillary first molars[2]. The COS further deepens as the permanent second molars erupt, and then becomes relatively stable into adulthood. This curve has a role in both determining the relative cusp heights of posterior teeth and discluding posterior teeth in anterior movements if the patient has anterior guidance[3]. The COS may also play a compensatory role as teeth continue to erupt until in contact with the opposing dentition, leading to incisors erupting superior to the functional occlusal plane and increasing the COS depth[4].

In Andrews' 1972 publication on the six keys of occlusion, his study of 120 casts with naturally occurring ideal occlusions found the COS was generally flat to mild in depth; therefore, a treatment objective in the straight wire appliance became leveling the plane of occlusion[5]. Disregarding the functional reasons for the presence of a COS, several authors have focused on how to estimate the additional arch length necessary for leveling. There is great variability in the equations and methods to estimate the effect leveling the COS will have, but the general consensus is that additional arch length will be necessary[6-10].

Knowing that additional length is needed, studies have also been performed to determine whether there is a correlation between the COS depth and the molar Angle classification. While there is disagreement in whether division 1 or division 2 have the deepest values, it has been consistently found that the COS is deepest in Class II dental malocclusions when compared to Class I and III[11-14]. In addition to the correlation of COS with Class II malocclusions, Xu found that deeper COS values were correlated with low mandibular plane angles[15]. This finding is reinforced by multiple authors who found COS to be more pronounced in hypodivergent patients when compared to normodivergent and hyperdivergent. Orthlieb found that hypodivergent patients exhibited a smaller COS radius, however Class II patients of all vertical skeletal patterns had a larger COS radius compared to Class I and III[16]. Kumari reported that the COS is negatively correlated to the Sn-GoGn angle, but not significantly correlated to FMA[17]. In contrast, Halimi stated that the depth of the COS is more pronounced in hypodivergent patients, but that this difference was not significantly correlated[18].

The curve of Spee (COS) is one of many factors that must be considered during treatment planning for the orthodontic patient. A deeper COS adds additional treatment complexities, especially when combined with patients presenting with hyperdivergent or hypodivergent mandibular planes due to the different treatment mechanics one must employ. To our knowledge, there are no studies to date that look for a correlation between the mandibular plane angle and the depth of the COS in Class II skeletal malocclusions. Specifically, previous studies did not discriminate based on skeletal classification, or focused exclusively on Class I malocclusions. Therefore, the purpose of this study is to build off previous unrelated findings; that COS is deeper in Class II skeletal malocclusions, and that COS is deeper in hypodivergent patterns. Specifically, the hypothesis being tested is that hypodivergent Class II skeletal patterns will exhibit a greater COS and that there is a correlation between the mandibular plane and the depth of the COS in class II malocclusions. The null hypothesis is that there will be no correlation between the COS depth and the mandibular plane angle.

Methods and Materials

This retrospective study was conducted with records of patients who previously presented for treatment. The following exclusion criteria were used:

1) A complete permanent dentition (third molars could either be extracted or unerupted)
2) A skeletal Class II profile (ANB greater than 4 degrees)
3) No previous orthodontic treatment (determined by review of the patient record)
4) Absence of periodontal disease
5) Dental casts and CBCT available
6) No craniofacial anomalies

From the list of patients who met these criteria, an additional search was performed to divide the potential records into three groups: hypodivergent (FMA less than 20 degrees), normodivergent (FMA between 20 and 29 degrees), and hyperdivergent (FMA greater than 29 degrees). From each of these groups, 20 patients were randomly selected to make up the total study population (60 patients).

For each patient, a reconstructed lateral cephalogram was created from the CBCT volume (Dolphin Imaging, 11.95 Premium, Patterson Dental, Chatsworth, CA) and the following measurements were determined: SNA, SNB, ANB, A-N perpendicular (A-N Perp), B-N perpendicular (B-N Perp), Pogonion-N perpendicular (Pog-N Perp), SN-MP, FMA, OP-MP, SN-OP, U1-NA, U1-SN, L1-NB, L1-MP. For the purposes of this study, a line extending through the overlapping cusps of the first molars and the first premolars established the functional occlusal plane (OP). The mandibular plane was measured from menton to constructed gonion.

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

The COS was measured following the method previously applied by Rozzi[19]. The mandibular occlusal plane was established by selecting three points: the distobuccal cusp of each mandibular second molar, 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 rectified by selecting a point halfway between the two edges. The depth of each cusp tip to this occlusal reference plane was measured. Cusp tips that were not in occlusal contact with an antagonist were not included in the measurements. From these values, the deepest cusp measurement for both the left and right side was recorded. These two values (left and right COS) were averaged for each patient and this value was used for the COS depth.

Overjet and overbite were measured following a method previously applied by Veli[13]. Overjet was a horizontal measurement between the incisal edge of the facial surface of the mandibular central incisor and the incisal edge of the facial surface of the maxillary central incisor. The most facially positioned maxillary central incisor was selected whenever there was a discrepancy between the two central incisors (Figure 2). Overbite was a vertical measurement between the incisal edges of the maxillary central incisor to the mandibular central incisor (Figure 2). The COS, overbite, and overjet measurements were all recorded in millimeters.

Statistical Analysis

Data was analyzed with descriptive and correlation statistics. A one-way ANOVA was performed to assess for significant differences in the COS depth between the three skeletal divergence groups. Additionally, Pearson's correlation coefficient calculations were accomplished to look for correlations between the multiple measured variables to the COS. To test the reliability of the measurements, 20 sets of records (3-D casts and lateral cephalograms) were randomly selected to have the procedure repeated 1 month later by the same rater.

Results

Our sample included 60 patients, composed of 28 females and 32 males. The age of the patients ranged from 13.2-46.2 years, with an average age of 25.5 years, and a mean of 23 years.

The COS average was deepest in hypodivergent patients (2.43mm), and shallowest in hyperdivergent (2.05mm), however the differences, calculated by One-way ANOVA, were not significant ($P > 0.05$) (Table 1).

The correlation analysis found that when looking at COS to all the variables aggregated, there was a small negative correlation to L1-NB ($p < 0.05$), and a large positive correlation to both overbite and overjet ($P = 0$) (Table 2). Separating the patients by skeletal divergence, in normodivergent patients the COS was positively correlated to U1-NA and overjet, and negatively correlated with both SNA and A-N perpendicular (Table 3). In hypodivergent patients the COS was negatively correlated to L1-MP and positively correlated to overbite. Finally, in hyperdivergent patients the COS was positively correlated to both overbite and overjet (Table 3).

Discussion

The results of this study failed to accept the hypothesis that the COS depth would be increased in hypodivergent skeletal Class II patients. The COS was not correlated to skeletal divergence (FMA or SN-MP). Because deepbite malocclusions have been correlated previously with hypodivergent skeletal patterns, and the COS is deeper in patients with deepbites, one would assume that a deeper COS would be found in hypodivergent patients[20]. However, the results of this study show there was no correlation between COS depth and the mandibular plane in skeletal Class II individuals, which agrees with previous studies[17,18]. The findings in this study are in contrast to Shannon who found COS to be inversely related to the mandibular plane angle[21].

Orthlieb found that hypodivergent patients exhibited a smaller COS radius, however Class II patients of all vertical skeletal patterns had a larger COS radius compared to Class I and III[16]. The difficulty in comparing the current study with Orthlieb's is the COS was measured as the radius of the curve of best fit from the condyle to the canine. This measurement can be affected by many other variables, such as mandibular length and ramus height, and discounts the role the mandibular incisors play in the development of the curve. It is also important to note that there is great variability in how the COS is measured in other studies. The COS has been measured from the distobuccal cusp of the second mandibular molar to the central incisor, from the distobuccal cusp of the second mandibular molar to the canine, and from the most overerupted incisor and molar. All of these variations can lead to significant differences in the COS depth.

Of significance, the COS depth was strongly correlated to both overbite and overjet measurements ($P = 0$). Filtering the data by skeletal divergence, both hypodivergent and hyperdivergent patients had large positive correlations with overbite. Additionally, normodivergent and hyperdivergent skeletal profiles had positive correlations with overjet. A previous study by Baydas found that overbite could explain 17.3% of the variance in the COS depth, and the findings of larger overbite and overjet measurements with increased COS depth are in agreement with the findings of our study[22]. This is further supported by El-Dawlatly who found that COS had the highest contribution to development of a deepbite amongst measured skeletal and dental values[23]. The positive correlation between overjet and COS is additionally reinforced by multiple other studies[16-18.24]. Andrews proposed one potential reason for this occurrence is due to the mandible continuing to grow after the maxillary growth ceases[5]. This growth leads to the lower anterior teeth being restricted by the maxillary anterior teeth, leading to potential continued eruption and retroclination, and ultimately crowding with a deep overbite and COS. The negative correlation between the L1-MP and COS depth lends credence to this theory.

Several studies have found that larger ANB values are correlated to increased COS depths[25-27]. The current study found no correlation between SNA, SNB, or ANB to COS, similar to the findings of Farella[28]. One explanation for this could be the previously mentioned studies included patients of varying skeletal classifications while our study exclusively looked at Class II, limiting the overall range of values collected. Repeating this study with Class I and III individuals would provide a more detailed examination into whether a correlation exists.

The COS was highly variable, ranging was 0.81mm to 5.05mm. Interestingly, both the highest and lowest COS values occurred in hyperdivergent patients, while the lowest COS average also occurred in hyperdivergent skeletal patients. The mean of the COS on the left (2.31mm) was deeper than the right (2.19mm), however this did not approach significance. This finding reinforces previous findings that there appears to be no significant difference in the COS when comparing the left and right[2,12,13]. When evaluated based on gender, females mean COS (2.20mm) was shallower than males (2.38mm) but the differences were not statistically significant. This contradicts one study with a similar sample size as the current study that found females had a deeper COS than men[29]. However, the findings are reinforced by multiple previous studies that the COS depth does not seem to be correlated to a specific gender[15,16,18,30].

As part of the inclusion criteria, the presence of a CBCT was selected to standardize the imaging modality for the entire study population. The advantage to this study was that using CBCT imaging allowed the researcher to standardize the reconstructed lateral cephalometric radiographs and eliminated magnification errors in linear measurements. It has previously been demonstrated that skull orientation does not affect the accuracy of skeletal measurements made using CBCT, eliminating positioning/orientation errors frequently seen with conventional two-dimensional imaging methods[31].

The conflicting results of this study to others may be the result of multiple factors: differences in the study groups (sample size, selection criteria, age range of patients, ethnicity, etc), cephalometric landmark variations, and the statistical tests performed. Based on the previous findings that the COS remains relatively stable into adulthood following the eruption of the complete permanent dentition, no attempts were made to restrict patients included in this study based on age[2]. Instead, the inclusion criteria was based on presence of a complete adult dentition (second molars fully erupted and in occlusion with their antagonist). The large range in patients ages could potentially lead to some biases in COS measurements, particularly due to the continued vertical eruption of teeth.

Another potential weakness of the patients selected for this study is that patients were not screened based on ethnicity. The authors are not aware of any studies comparing the COS depth directly between different ethnic groups; however, it cannot be disproven that the COS is not impacted by ethnic variations. Finally, this study made no effort to screen patients based on both their skeletal and Angle molar relationship. Instead, only the skeletal relationship was selected as a screening criteria. This could lead to instances of Angle Class I and III individuals being represented in the populations due to extremes of skeletal divergence. Future studies could be conducted selecting individuals possessing both Angle and skeletal Class II relationships.

Conclusion

- The COS depth was not correlated to the mandibular plane angle in skeletal Class II individuals.
- The COS depth was positively correlated to both overbite and overjet.
- The COS was negatively correlated with L1-MP.

Competing Interests

The authors declare that they have no competing interests.

Ethics Approval

Not applicable

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Figure Legends

Figure 1

The COS was established by selecting three points on each cast: the distobuccal cusp tip of each second molar, and the midpoint between the incisal edges of the central incisors. From this reference plane, the cusp tip of each tooth was measured. The deepest measurement was recorded for both the patient's left and right sides, and then averaged.

Figure 2
Overbite was a vertical measurement between the incisal edges of the maxillary central incisor to the mandibular incisor. Overjet was a horizontal measurement between the incisal edge of the facial surface of the mandibular central incisor and the incisal edge of the facial surface of the maxillary central incisor. Both measurements were measured from the maxillary central incisor for both sides and the values were averaged.

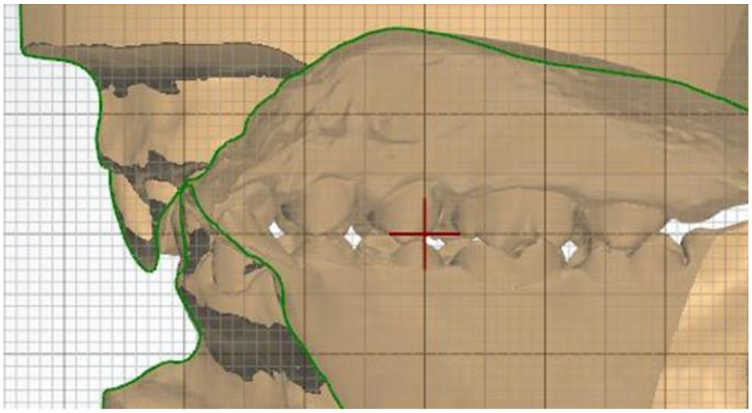
Table 1
COS Average based on skeletal divergence.

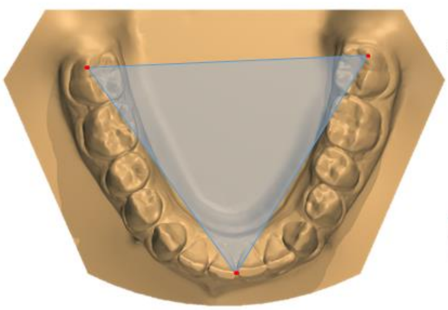
Table 2
Correlation of measured values to COS without separation into skeletal divergence. **Bolded values are significant at P < 0.05.**

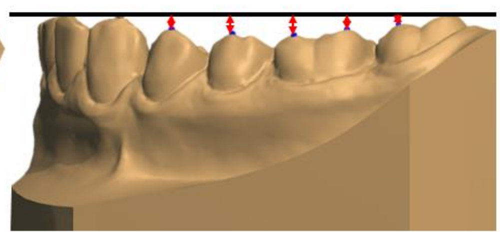
Table 3
Correlation of measured values to COS separated by skeletal divergence. **Bolded values are significant at P < 0.05.**

Group		SNA	SNB	ANB	A-N Perp	B-N Perp	Pog-N Perp	SN-MP	FMA	OP-MP	SN-OP	U1-NA	U1-SN	L1-NB	L1-MP	COS Average	Overbite	Overjet
Hypodivergent	Mean	87	81.1	5.91	3.71	-3.6	-1.38	22.26	15.53	12.72	9.55	2.64	102.1	5.58	102.1	2.43	2.43	4.65
	SD	2.94	2.49	1.39	3.62	4.9	5.09	2.61	3.04	3.01	3.61	4.92	13.61	3.46	8.36	0.79	0.79	1.82
	P Value	0.98	0.46	0.19	0.6	0.93	0.66	0.56	0.91	0.29	0.65	0.17	0.2	0.11	**0.04**		**0**	0.57
	Pearson Correlation	-0	-0.18	0.3	0.13	0.02	0.11	0.14	0.03	0.25	-0.11	-0.32	-0.08	-0.37	**-0.47**		**0.63**	0.14
Normodivergent	Mean	83.3	77.8	5.48	0.35	-8.53	-7.91	32.88	25.77	19.14	13.75	4.16	102.6	7.29	97.88	2.4	4.53	4.68
	SD	4.46	3.88	1.36	3.52	4.99	5.22	1.99	1.68	3.45	4.47	3.53	9.8	2.56	6.15	0.62	1.59	2.63
	P Value	**0.04**	0.06	0.19	**0.03**	0.06	0.1	0.45	0.77	0.38	0.73	**0.01**	0.15	0.94	0.12		0.47	**0.005**
	Pearson Correlation	**-0.5**	-0.43	-0.3	**-0.5**	-0.42	-0.38	0.18	0.07	0.21	-0.08	**0.56**	0.33	-0.02	0.36		0.17	**0.61**
Hyperdivergent	Mean	81.5	75	6.49	-1.02	-13.2	-13.72	42.27	34.8	22.67	19.61	3.89	99.42	9.25	94.21	2.05	3.39	4.38

Group		SNA	SNB	ANB	A-N Perp	B-N Perp	Pog-N Perp	SN-MP	FMA	OP-MP	SN-OP	U1-NA	U1-SN	L1-NB	L1-MP	COS Average	Overbite	Overjet
	SD	3.31	4	1.61	2.86	5.64	5.91	4.32	3.14	3.03	3.7	2.32	8.64	3.14	7.35	0.92	2.32	2.19
	P Value	0.92	0.73	0.32	0.47	0.37	0.34	0.39	0.63	0.98	0.32	0.91	0.74	0.54	0.85		**0**	**0**
COS Average	Mean	83.95	77.99	5.96	1.01	-8.44	-7.67	32.47	25.36	18.17	14.3	3.56	101.36	7.37	98.06	2.3	4.66	4.57
	SD	4.26	4.28	1.49	3.85	6.45	7.36	8.8	8.37	5.19	5.69	3.74	10.8	3.38	7.91	0.79	2.27	2.2
	P Value	0.87	0.72	0.64	0.77	0.84	0.86	0.13	0.14	0.63	0.06	0.94	0.76	**0.04**	0.96		**0**	**0**
	Pearson Correlation	-0.02	-0.05	0.06	-0.04	-0.03	0.02	-0.2	-0.19	-0.06	-0.25	-0.01	-0.04	**-0.27**	0.01		**0.58**	**0.51**







Group		COS
Hypodivergent	Mean	2.29
	SD	0.66
	Range	1.05-3.59
Normodivergent	Mean	2.4
	SD	0.62
	Range	1.46-3.84
Hyperdivergent	Mean	2.05
	SD	0.92
	Range	0.81-5.05