Original article

Development of the curve of Spee in Class II subdivision malocclusion: a longitudinal study

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Abstract

Objective: To compare the depth of curve of Spee (COS) in Class I and II sides of Class II subdivision malocclusion longitudinally and to describe the changes in the COS in relation to dental arch over time.

Materials and Method: The study group comprised 17 subjects exhibiting Class II subdivision malocclusion. The depth of COS, intermolar width, distances from mesial anatomic contact points of the first permanent molars to the contact point of the central incisors in Class I and II sides and arch length in mandible were analysed on digital models in three different time points based on cervical vertebral maturation (T1; mean age: 12.4 years, T2; mean age: 15.1 years, and T3: mean age: 19.1 years). Pearson's correlation coefficients were calculated and linear multiple regression analysis with enter method was carried out.

Results: No significant differences were found in the depth of COS between Class I and II sides in all time periods. The mesiobuccal cusp of the first molar was the deepest part of COS in both sides and in all time periods, with a maximum depth of 2.37±0.83 mm in T1 and a minimum depth of 1.91±0.66 mm in T3. Between baseline and final follow-up; the depth of COS, ach length, and distance in Class I side decreased significantly. Arch length had a significant correlation with the depth of COS (r = 0.471) in T3.

Conclusions: As the depth of COS did not differ between either the Class II or I sides, the same mechanics can be used to level the COS in either sides of the mandibular arch.

Introduction

Unilateral Class II malocclusions were classified as Class II subdivision by Angle (1). This type of malocclusion with asymmetric occlusal relationships; Class II on one side of the dental arch and Class I on the other side, often pose present difficulties in orthodontic treatment planning (2). Although some studies have already described many characteristics of Class II subdivision malocclusions (3, 4), some questions are still available about the origin and etiologic factors of unilateral malocclusions.

Alavi et al. (3) were the first to determine that Class II subdivisions result mainly from asymmetry in the mandibular first molars. Rose et al. (4) concluded that Class II subdivisions occur from distal positioning of the mandibular first molars on Class II side. Janson et al. (5) reported that the components that contributed to the asymmetric sagittal relationship in Class II subdivision malocclusions were mainly dentoalveolar, and the primary contributor to the differences between Class II subdivision malocclusion and the normal occlusion was the distal positioning of the mandibular first molars on Class II side. A secondary contributor was the mesial positioning of the maxillary first molars on Class II side. Similarly, Azevedo et al. (2) evaluated Class II subdivision patients with apparent facial asymmetry and concluded that the subdivision was primarily dentoalveolar with minimal skeletal involvement.

The ‘curve of Spee’ (COS) is a naturally occurring phenomenon in the human dentition and this curve of occlusion was first described as the line on a cylinder tangent to the anterior border of the condyle, the occlusal surface of the second molar, and the incisal edges of the mandibular incisors (6).
Increased COS in the mandibular dentition is a common feature of patients undergoing orthodontic treatment; hence evaluation of the depth of COS is important for the orthodontic diagnosis and treatment planning. Andrews (7) described the six keys of occlusion and found that the COS ranged from flat to mild in subjects with proper occlusion. He also stated that the levelling and flattening of the COS should be the goal of treatment. Flattening of the COS is accomplished by anterior intrusion, posterior extrusion, or a combination to achieve an ideal occlusion (8).

Class II subdivision malocclusions present characteristics of both Class I and II malocclusions. Therefore, an occlusal asymmetry between Class I and II sides of the dentition would be expected. As no study has been published on the longitudinal assessment of the COS in Class II subdivision malocclusions, the purpose of this study was to evaluate the depth of COS and relate the COS with the arch measurements in Class II subdivision malocclusion, aiming to contribute to the increase in knowledge about the development of the COS over time. The null hypotheses tested were that:

1. The amount of the depth of COS and the deepest point of the COS did not differ between Class I and II sides in Class II subdivision subjects;

2. There were no significant changes in the depth of COS over time.

**Materials and methods**

The sample was selected retrospectively from the files of the University of Michigan Growth Study and longitudinal records of orthodontically untreated subjects with Class II subdivision malocclusions were included in this study.

Sample selection was based exclusively on the initial antero-posterior dental relationship, regardless of any dental or skeletal characteristic. The selection criteria were:

1. Class II molar relationship ≥ 1/2 of a premolar width on one side and Class I molar relationship on the other side from buccal aspect and the mesiopalatal cusp of the upper first molar occludes with the mesial triangular fossa of the lower first molar from lingual aspect (9, 10),

2. All permanent teeth present up to the second molars, 3. No supernumerary or congenitally missing teeth excluding third molars or teeth with extensive restorations or gross decay, 4. No ectopic teeth or anomalies in tooth shape, 5. No previous orthodontic treatment, 6. No crowding or, at most, symmetrical crowding of up to 3mm, 7. No anterior or posterior crossbites, 8. Clear lateral cephalograms at three time points available for all selected subjects. Additionally, casts with fractured cusps or severe attrition, molars or premolars on which more than two-thirds of the occlusal surface had been reconstructed were excluded.

A final sample size of 17 pairs of dental casts (8 boys, 9 girls) and a total of 34 sides (Class I and II) were included for analysis. Cervical vertebral maturation was assessed for each subject on the lateral cephalograms (11) and T1 corresponded to CS3, T2 corresponded to CS4, and T3 corresponded to CS5. The mean ages at T1, T2, and T3 were 12.4 ± 0.1, 15.1 ± 0.6, and 19.1 ± 0.6 years, respectively.

All patients included in this study had Type 1 Class II Subdivision malocclusion characterized by distal positioning of the mandibular first molar on Class II side and coincidence of the maxillary dental midline with the facial midline and deviation of the mandibular midline (12). Dental midlines were determined on PA radiographs, passing through the root of crista galli perpendicular to a line connecting the most superior points on the orbital contours (3).

All plaster models were transformed into digital format by a three-dimensional (3D) model laser scanner (D250 3D Dental Scanner; 3Shape A/S, Copenhagen, Denmark). The digital models were analyzed by one investigator (MAO) using 3Shape Orthoanalyzer, version 1.0 software (3Shape A/S). The depth of COS was measured as following:

Horizontal reference plane comprised a line between central incisors and distobuccal cusp tips of mandibular second molars was constructed using the grids available on the dedicated software. The perpendicular distances from the buccal cusp tips of the involved teeth to constructed line through the horizontal reference plane were evaluated, and deepest point calculated as the value for the depth of COS for Class II and I sides (Figure 1). The depth was defined as the average of both sides.

Also, intermolar width (the distance between mesiobuccal cusp tips or estimated cusp tips in cases of wear facets), distances from mesial anatomic contact points of the first permanent molars to the contact point of the central incisors in Class I and II sides and arch length (the sum of distances in Class I and II sides) (13) were measured (Figure 2).

**Figure 1.** The perpendicular distances from each buccal cusp tip.
Ten randomly selected sets of digital models were redigitized and remeasured 2 weeks after the first set of recordings to calculate the method error by means of Dahlberg’s formula (14) and intraexaminer reliability was quantified by using the intraclass correlation coefficient (ICC).

**Statistical analysis**

All statistical analyses were performed using the Statistical Package for Social Scientists software package (SPSS for Windows, version 20.0, SPSS Inc, Chicago, IL, USA). The normality properties of the 15 variables (5 distinct variables at 3 time points) were checked using Shapiro–Wilk test yielding satisfaction of normality assumption on 13 out of 15 variables.

Paired sample t-test was used for side comparisons and Pearson’s correlation coefficients were calculated to determine the linear associations among arch length, intermolar width, R, L, and the depth of COS. To assess the contribution of individual variables to the depth of COS, linear multiple regression analysis with enter method was carried out.

Parametric repeated measures analysis of variance (ANOVA), considered as an appropriate statistic since it would give more statistical power compared to nonparametric test when normality is generally achieved, was performed to compare the time points on five response variables; i.e. arch length, intermolar width, R, L, and the depth of COS. All values were considered significant when \( P < 0.05 \).

**Results**

The errors for the measurements varied between 0.2 and 0.5 mm and high degree of intraexaminer reliability was noticed for all variables. (ICC = 0.948–0.993).

The mean, standard deviation (SD), minimum, and maximum values of average perpendicular distances from the buccal cusp tips of the involved teeth to constructed line in all time periods were presented in Table 1. The results of paired sample t-test revealed no significant differences in the depth of COS between Class I and II sides in all time periods \((P > 0.05)\) (Table 2). The mesiobuccal cusp of the first molar was the deepest part of the COS in all time periods, with a maximum depth of \(2.37 \pm 0.83\) mm in T1 and a minimum depth of \(1.91 \pm 0.66\) in T3 (Table 1). The depth of COS decreased between baseline and final follow-up.

The mean and SD of arch length, distance in Class II side, distance in Class I side and intermolar width were measured in all time periods (Table 3). Pearson’s correlation coefficient was calculated between arch length, distance in Class II side, distance in Class I side, and intermolar width and the depth of COS (Table 3). All variables decreased over time. The results indicated statistically significant positive correlation between the depth of COS and the distance in Class I side \((r = 0.471)\) in T3. The COS at each of three time points were weakly and insignificantly correlated with arch length, distance in Class II side and intermolar width. Those insignificant correlations did lead not to examine relationships using multiple linear regressions.

The multiple linear regression analysis with enter method revealed (Table 4) that arch length had a significant contribution.
to the depth of COS in T3. The measured variables explained 16.7, 17.7, and 38.4% of the total variance of the depth of COS in T1, T2, and T3, respectively.

Repeated measures ANOVA revealed statistically significant differences in the depth of COS, arch length, and the distance in Class I side among time periods (Table 5). On the other hand, the distance in Class II side showed statistically significant differences only between T1 and T3 and no significant differences were found in intermolar width among time periods. Between baseline and follow-up periods; the depth of COS, arch length, and the distance in Class I side showed statistically significant decreases.

On the basis of current results, the null hypotheses of the study were failed to be rejected.

Discussion
An understanding of the adaptive longitudinal changes in occlusion is useful in the treatment and retention planning. Class II subdivision malocclusions with their asymmetric occlusal relationships often present treatment difficulties (3). Therefore, our primary concern was to evaluate the longitudinal changes in the COS in Class II subdivision malocclusion. By this way, the differential mechanics to be used to level the COS in either Class II or I sides were evaluated.

Lack of gender dimorphism in the depth of COS has been reported in literature (15, 16). Carter and McNamara (17) examined the changes in the dental arches between late adolescence and the fifth or sixth decade of life in untreated subjects and reported no difference in the depth of COS between males and females when measured from the dental casts taken before treatment. Similarly, Xu et al. (18) reported that there is no significant difference in the COS between Japanese males and females. Therefore no attempt was made to separate the sample according to gender in this study. Also, sample selection was performed according to the initial antero-posterior dental relationship, regardless of any other dentoalveolar or skeletal characteristics. It has already been reported that the main components contributing to the asymmetric antero-posterior relationship in a patient with a Class II subdivision malocclusion are dentoalveolar characterized by the distal positioning of the mandibular first molar on Class II side and less often by mesial positioning of the maxillary molar on Class II side (5). Moreover, the influence of craniofacial morphology on the COS has been systematically investigated in very few studies and with conflicting results (19, 20). Farella et al. (21) investigated the relationship between the COS and craniofacial morphology, and concluded that the COS was influenced only to a minor extent by craniofacial morphology.

Table 1. Average perpendicular distances. n, sample size; Min, minimum; Max, maximum; SD, standard deviation.

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Time Period</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral incisor</td>
<td>T1</td>
<td>0.181</td>
<td>0.299</td>
<td>-0.390</td>
<td>0.760</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.030</td>
<td>0.252</td>
<td>-0.440</td>
<td>0.553</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>-0.065</td>
<td>0.283</td>
<td>-0.830</td>
<td>0.390</td>
</tr>
<tr>
<td>Canine</td>
<td>T1</td>
<td>0.191</td>
<td>0.331</td>
<td>-0.935</td>
<td>1.085</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.060</td>
<td>0.310</td>
<td>-0.935</td>
<td>0.885</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>-0.123</td>
<td>0.495</td>
<td>-1.030</td>
<td>0.495</td>
</tr>
<tr>
<td>First premolar</td>
<td>T1</td>
<td>1.359</td>
<td>0.740</td>
<td>0.185</td>
<td>3.500</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>1.030</td>
<td>0.713</td>
<td>0.000</td>
<td>2.695</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>0.739</td>
<td>0.712</td>
<td>-0.185</td>
<td>2.350</td>
</tr>
<tr>
<td>Second premolar</td>
<td>T1</td>
<td>2.156</td>
<td>0.917</td>
<td>0.800</td>
<td>4.385</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>1.684</td>
<td>0.722</td>
<td>0.685</td>
<td>3.055</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>1.323</td>
<td>0.785</td>
<td>-0.095</td>
<td>2.750</td>
</tr>
<tr>
<td>First molar</td>
<td>T1</td>
<td>2.370</td>
<td>0.837</td>
<td>1620</td>
<td>4.610</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>2.025</td>
<td>0.648</td>
<td>1230</td>
<td>3.445</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>1.911</td>
<td>0.669</td>
<td>0.970</td>
<td>3.305</td>
</tr>
</tbody>
</table>

Table 2. Side comparison of the depth of curve of Spee (mm). n: sample size; SD, standard deviation.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Measurements</th>
<th>Mean</th>
<th>SD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Arch length</td>
<td>60.846</td>
<td>2.504</td>
<td>0.382</td>
</tr>
<tr>
<td>T2</td>
<td>Distance in Class I side</td>
<td>30.400</td>
<td>1.364</td>
<td>0.077</td>
</tr>
<tr>
<td>T3</td>
<td>Distance in Class II side</td>
<td>30.446</td>
<td>1.509</td>
<td>0.431</td>
</tr>
</tbody>
</table>

Table 3. Pearson correlation coefficient for the listed variables. SD, standard deviation; r, correlation coefficient.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Measurements</th>
<th>Mean</th>
<th>SD</th>
<th>P</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Arch length</td>
<td>60.846</td>
<td>2.504</td>
<td>0.382</td>
<td>0.224</td>
</tr>
<tr>
<td>T2</td>
<td>Distance in Class I side</td>
<td>30.400</td>
<td>1.364</td>
<td>0.077</td>
<td>0.362</td>
</tr>
<tr>
<td>T3</td>
<td>Distance in Class II side</td>
<td>30.446</td>
<td>1.509</td>
<td>0.431</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Table 4. Results of multiple regression analysis. SD, standard deviation; Sp, is the curve of Spee; B, is the unstandardized regression coefficient; SE B, standard error of B; β, standardized regression coefficient.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Measurements</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Arch length</td>
<td>-0.099</td>
<td>0.166</td>
<td>-0.297</td>
<td>0.167</td>
</tr>
<tr>
<td>T2</td>
<td>Distance in Class II side</td>
<td>0.383</td>
<td>0.302</td>
<td>0.625</td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>Distance in Class II side</td>
<td>0.233</td>
<td>0.174</td>
<td>0.843</td>
<td>0.167</td>
</tr>
<tr>
<td>T4</td>
<td>Arch length</td>
<td>0.065</td>
<td>0.078</td>
<td>-0.221</td>
<td></td>
</tr>
<tr>
<td>T5</td>
<td>Arch length</td>
<td>0.500</td>
<td>0.198</td>
<td>1.774*</td>
<td>0.384</td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01, ***P < 0.001.
Table 5. Statistical comparison of the curve of Spee (COS), distances in both sides, arch length and intermolar width measurements using repeated measures analysis of variance (ANOVA). SD, standard deviation.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Multivariate test</th>
<th>Within-subjects effects</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F_{a(2)}$</td>
<td>$\eta^2$</td>
<td>$F_{a(2)}$</td>
<td>$\eta^2$</td>
<td>Mean</td>
</tr>
<tr>
<td>COS</td>
<td>7.570***</td>
<td>0.502</td>
<td>13.025***</td>
<td>0.449</td>
<td>2.377</td>
</tr>
<tr>
<td>Arch length</td>
<td>14.826***</td>
<td>0.664</td>
<td>20.427***</td>
<td>0.561</td>
<td>6.084</td>
</tr>
<tr>
<td>Distance in Class II side</td>
<td>7.023*</td>
<td>0.484</td>
<td>9.034***</td>
<td>0.361</td>
<td>30.40</td>
</tr>
<tr>
<td>Distance in Class I side</td>
<td>11.672*</td>
<td>0.609</td>
<td>18.189***</td>
<td>0.532</td>
<td>30.44</td>
</tr>
<tr>
<td>Intermolar width</td>
<td>1.056</td>
<td>0.123</td>
<td>1.602</td>
<td>0.091</td>
<td>44.48</td>
</tr>
</tbody>
</table>

Multivariate F ratios were generated from Pillai’s statistic. Means in a row sharing the same subscript are not significantly different from each other. *P < 0.05; **P < 0.01; ***P < 0.001.

There is little consensus in the literature concerning the measurement of the depth of COS. Baldridge (22) used the perpendicular distances on both sides and Bishara et al. (23) used the average of the sum of perpendicular distances to each cusp tip. Braun et al. (24) and Braun and Schmidt (25) used the sum of the maximum depth on both sides. However, these measurements made on the plaster models or using standardized photographs (26) by means of caliper (27).

Recent advances in 3D technology allow creating computerized study model of plaster cast and enable to perform precise measurements using designated software (28, 29). Sousa et al. (30) evaluated the reliability of measurements made on 3D digital models obtained with 3Shape D-250 surface laser scanner and concluded that linear measurements on digital models were accurate and reproducible. Gracco et al. (31) concluded that measurements carried out on 3D models are a valid and reliable alternative to those currently used on plaster models in orthodontic practice, with the advantage of significantly reducing measurement times. Considering the ease of use and reduced time, digital models were used in the present study.

The deepest point of the COS was found at the mesiobuccal cusp of the first molar for all investigated time points in the current study. All patients included in this study had Type 1 Class II Subdivision malocclusion characterized by distal positioning of the mandibular first molar on Class II side. Due to distal positioning of the mandibular first molar on Class II side, a change in placement of the deepest point of the COS would be expected over time. There are several reports in the literature concerning the deepest point of the COS. Koyama (32) reported the deepest point as the second premolar area. On the other hand, in accordance with the present findings, Garcia (33) reported that the deepest point in most patients was at the mesiobuccal cusp of the permanent first molar.

Indeed, due to asymmetric occlusal relationships in Class II subdivision malocclusion, any difference would be expected in the depth of COS due to distal positioning of the first molar. However, the data obtained in this study indicated no significant differences in the depth of COS between Class I and II sides in all time points. Marshall et al. (34) examined the development of the COS longitudinally in a sample of untreated subjects with normal occlusion from the deciduous dentition to adulthood and found no significant differences in the depth of COS between either the right or left sides of the mandibular arch. The authors think that as the depth of COS did not differ in either sides of the mandibular arch, the same mechanics can to be used to level the COS. However, in case of unilateral mechanics to be used for the correction of Class II side, such as Class II elastics, the clinician should consider the changes of COS.

The depth of COS decreased between baseline and final follow-up in the present study. Marshall et al. (34) measured the depth of COS at seven time points from ages 4 (deciduous dentition) to 26 (adult dentition) years and concluded that the depth was minimal in the deciduous dentition and its greatest increase occurred in the early mixed dentition as a result of differential eruption of the mandibular permanent first molars and incisors relative to the deciduous second molars. They further concluded that COS maintained its depth until it increased to maximum depth with the eruption of permanent second molars and then remained relatively stable into late adolescence and early adulthood. Although Marshall et al. (34) examined the development of the COS in subjects with normal occlusion; our finding is consistent with the study of Marshall et al. (34). On average, eruption of the mandibular permanent first molars precedes the maxillary permanent first molars by 1–2 months, and the mandibular permanent central incisors precede the maxillary permanent central incisors by 12 months. Also eruption of the mandibular second molars precedes their maxillary antagonists by 6 months (35, 36). Marshall et al. (34) reported that unopposed mandibular permanent first molar and incisor eruption beyond the established mandibular occlusal plane, followed by relatively unopposed mandibular second molar led to deepening in the COS.

The authors have already reported a statistically significant decrease in mandibular intermolar width in the same untreated subjects over a long period of time (37). Ward et al. (38) compared the fundamental arch width changes with and without treatment over 20 years and reported a small but insignificant decrease in lower intermolar arch width for the untreated group between baseline and final follow-up. It should be noted that the intermolar width and distance in Class I or II side might change during the long time observation period because of the changes in arch form. Many factors influence arch form and therefore, arch width changes must not be considered in isolation (39).

Consistent with our finding, several studies have indicated a reduction in arch length through time (17, 23). Statistical analysis revealed that arch length had a significant contribution to the depth of COS in T3. Arch length together with the distance in Class II side and intermolar width explained 38.4% of the total variance of the depth of COS in final follow-up period. Baldridge (22) and Garcia (33) found a linear relationship between arch circumference and the levelling of COS.

The presence of longitudinal records that fulfill the comprehensive inclusion criteria represents the specificity of this study. However, due to the small sample size which was the limitation of this study, the results should be interpreted cautiously, requiring further confirmation with larger samples of subjects.
Conclusion

1. There are no significant differences in maximum depth of COS between either Class II or I sides of the mandibular arch.
2. Arch length, distance in Class II side and intermolar width explained 38.4% of the total variance of the depth of COS in final follow-up period.
3. Arch length had a significant contribution to the depth of COS in Class II subdivision malocclusion in final follow-up period.
4. The depth of COS decreased between baseline and final follow-up period.
5. As the depth of COS did not differ between either Class II or I sides, the same mechanics can be used to level the COS in either sides of the mandibular arch.

Acknowledgments

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References