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Association of Mandibular Incisor Proclination and Mandibular Arch Widths with The Levelling of Curve of Spee

Nadia Sharafat [1]*, Imran Tajik [2], Nazir Ahmad [3], Qazi Ahmad [4], Mehran Khan [5]

[1] Resident, Orthodontics Department, Sardar Begum Dental Hospital, Gandhara University, Peshawar, Pakistan
[2] Department of Orthodontics, Sardar Begum Dental Hospital, Gandhara University, Canal Road, Academy Town, Peshawar, Pakistan
[3] Professor Orthodontics, Sardar Begum Dental Hospital, Gandhara University, Peshawar, Pakistan.
[4] Resident, Orthodontics Department, Sardar Begum Dental Hospital, Gandhara University, Peshawar, Pakistan
[5] Resident Prosthodontics Department, Khyber College of Dentistry, Peshawar, Pakistan

*** Corresponding Author:** Nadia Sharafat
Address: Orthodontics Department, Sardar Begum Dental Hospital, Gandhara University, Peshawar, Pakistan
Email: nadiasharafat3@gmail.com

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Abstract

Background: In this study, we aimed to determine the changes in mandibular incisor proclination and mandibular arch widths after leveling the curve of Spee (COS).
Methods: Patients included in this quasi-experimental study were scheduled for fixed orthodontic treatment with a non-extraction therapy in the mandibular arch, no posterior crowding, eruption of all mandibular teeth except third molars, no spacing and Little's irregularity index greater than 2. The COS depth and mandibular arch widths (inter-canine and inter-molar widths) were measured on plaster casts and recorded in millimeters. Mandibular incisors inclinations were measured on a cephalometric radiograph according to the incisor mandibular plane angel (IMPA) and lower incisor to NB (L1) angle. The pre-treatment and post-treatment values were compared using paired sample T-test. Pearson correlation was used to analyze the association between COS changes and other variables. P-value <0.05 was considered statistically significant.
Results: A total of 58 subjects with an average age of 25.10±6.81 years participated in this study. COS depth values significantly reduced after treatment (2.34±0.78mm vs 1.75±0.56mm), (P<0.001). Average IMPA and L1-NB values significantly increased following COS flattening (P<0.001). Mandibular inter-canine and inter-molar widths also showed significant increase after treatment (P<0.001). Pearson's correlation revealed a significant and inverse correlation between COS changes and mandibular arch width and mandibular incisor proclination values (P<0.001 for both). Patient's age and gender did not have a significant effect on COS depth.
Conclusion: Flattening of COS leads to an increase in lower incisor proclination and mandibular arch width.

Keywords: Cephalometry, Orthodontics, Interceptive, Orthodontic Wires, Treatment Outcome

Background

The curve of Spee (COS) was first described by Ferdinand Graf von Spee in 1980. Spee analyzed a number of human skulls from the sagittal profile view and predicted the occlusal curvature. The line of occlusion was defined as a line tangent to the surface of a cylinder perpendicular to the sagittal plane on the anterior border of the condyle, the occlusal surfaces of second mandibular molars and the incisal edges of the mandibular incisors (1).

Currently, the COS commonly refers to an anteroposterior curve that is tangent to the incisal edges and buccal cusp tips of mandibular dentition, when viewed in the sagittal plane (2-5).

The literature claims that by increasing the crush/shear ratio produced on food between the posterior molars; the COS enhances the efficiency of occlusal forces and plays an important biomechanical role in masticatory function (6,7). Andrews (8) described the six characteristic features of normal occlusion and proposed that COS depth in individuals with optimal occlusion ranged from flat to mild. Furthermore, he believed that a deep COS may make it almost impossible to achieve a Class I canine relationship, and COS was associated with post-treatment relapse. Andrews proposed that flattening the occlusal plane should be an important treatment goal in orthodontic treatment plans.

Studies have reported a flatter COS in deciduous dentitions compared to permanent dentitions and an increase in COS depth with the eruption of the first permanent mandibular molars and permanent mandibular incisors (4, 9). The COS remains relatively stable once established (10, 11). Various studies have reported various depths of COS in different malocclusions; the greatest depth was observed in Class II division 1, Class II division 2, Class I, and Class III subjects, in descending order (12-14).

Tahira et al. (15) found that the greatest COS depth values are observed in normal angled followed by high-angle and low-angle subjects. Rozzi et al. (16, 17) reported that the leveling of COS in low-angle subjects is established through proclination and intrusion of lower incisors, whereas in high-angle subjects, the COS flattening is mainly achieved through extrusion and uprighting of posterior mandibular teeth. The high-angle group also demonstrated a higher COS stability after treatment.

A study conducted by Pandis et al. (18) revealed that the establishment of a flat COS mainly occurred through mandibular incisor proclination. A four-degree increase in Incisor-Mandibular angle occurred with 1mm of leveling without increasing the arch widths. However, after measuring the pretreatment and post-treatment plaster models, Afzal and Ahmed (19) concluded that the notion of 1mm of arch circumference necessary to level each millimeter of COS is overestimated

Currently, there is a lack of evidence regarding the changes occurring in mandibular arch width as a result of COS flattening with straight wire appliances. Hence, the aim of this study was to assess the effects of COS leveling with straight wire appliances on mandibular incisors proclination and mandibular arch width changes.

Methods

This quasi-experimental study was conducted from December 2020 - June 2021. Participants were recruited through a non-probability consecutive sampling technique. The protocol of this study was approved by the Ethical committee of Sardar Begum Dental College, Gandhara University and patients were enrolled after obtaining verbal informed consent.

Individuals fulfilling the following inclusion criteria were included in the study: Non extraction treatment plan in mandibular arch, no posterior crowding, fully erupted mandibular teeth except third molars with no spacing, and Little's irregularity index (LII) greater than 2.

A standard manual Vernier calliper (Mitutoyo Co., Japan) was used to measure LII for assessment of lower anterior crowding. This index score is the sum of horizontal displacement of anatomical contact points of lower anterior teeth. In all participants pre-adjusted edgewise of 0.022-inch slot brackets were used. The arch wires sequence for COS levelling was 0.014 NiTi (Nickel-Titanium), 0.016 NiTi, 0.018 SS (Stainless steel), and finally 0.017 x 0.025 SS. All patients were recalled for adjustments monthly. The COS was measured on plaster models using lower incisors and second molars as reference points. It was measured by a flat plane formed from the incisal edge of the mandibular central incisors to the distal cusp tip of the second molars in millimeters. The furthermost depth from this plane was recorded. Average COS was calculated for both sides.

Pre-treatment and post-treatment changes in the arch width, i.e. inter-canine and inter-molar widths, were recorded on dental casts using a Vernier calliper. The inter-canine width was measured as the distance between the cusp tips of the left and right canine. The inter-molar width was considered as the distance between the central grooves of the left and right molar. Pre-treatment and post-treatment lateral cephalograms were traced. The inclinations of the mandibular incisors before and after COS leveling were assessed on the traced pre-treatment and post-treatment lateral cephalograms. Mandibular incisor inclinations were measured using incisor mandibular plane angle (IMPA) and lower incisor to NB (L1-NB) angles. All measurements were conducted and recorded by an experienced orthodontist (NS).

To ensure measurement accuracy, all measurements were repeated by an independent evaluator who was unaware of the study protocol. A mean value was obtained from the values provided by the first and second evaluators and was used for statistical analysis. A third operator, who was also unaware of the study protocol, was also engaged to oversee the second operator during the measurement process to prevent any potential errors.

The sample size was calculated using OpenEpi software assuming a 95% confidence interval and 80% power. The sample size was determined using previous results provided by Pandis et.al (18) regarding pre-treatment and post-treatment inter-molar width values. A sample size of 58 cases was deemed necessary.

SPSS software version 22.0 (SPSS Inc., Chicago, USA) was used for data analysis. Descriptive statistics were presented as frequencies and percentages for categorical variables like LII and mean ± standard deviation (SD) for continuous variables such as age, COS, incisor proclination and arch width. Shapiro Wilk test was used to establish the normality of data distribution. Pre-treatment and post-treatment COS, incisor proclination and mandibular arch widths were compared using paired sample T-tests. Pearson correlation test was used to determine the association between changes in COS values and age, gender, changes in inter-canine and inter-molar width, IMPA, and L1-NB. Effect modifiers such as age and gender were addressed through stratification. Post-stratification paired t-test was applied. P-value <0.05 was considered statistically significant.

Results

This study included 58 subjects with an average age of 13-40 years and an age range of 25.10±6.818 years. Gender distribution frequency consisted of 34 (58.6%) female and 24 (44.4%) male patients. Patients were evaluated and classified according to LII. The most common degree of irregularity was moderate (n=29, 50%) followed by severe (n=16, 27.6%) minimum (n=11, 19%) and very severe (n=2, 3.4%), in descending order of frequency.

After orthodontic treatment was completed, average COS depth decreased from 2.34±0.78mm to 1.75±0.56 mm. There was an increase in mandibular incisor proclination according to the changes in IMPA and L1-NB angles after COS leveling. There was an increase in mandibular arch width regarding mean inter-canine and inter-molar values, following COS leveling. According to the paired-sample T-test, all these changes were statistically significant (P<0.001 for all). Table 1 presents these findings in greater detail.

Table 2 illustrates male and female subjects' mean pre- and post-treatment orthodontic values. Regardless of the gender, post-treatment COS depth values were significantly less compared to before treatment (P<0.001). However, no significant difference was established between the mean COS values among different the genders. In both male and female subjects, the mean values indicating mandibular proclination (IMPA, L1-NB) and mandibular arch widths (inter-molar and inter-canine widths) significantly increased after COS leveling (P<0.001 for all).

The Pearson correlation coefficient between COS leveling and the changes in mandibular arch widths and mandibular incisor proclination, revealed a statistically significant and inverse correlation was between COS flattening and inter-molar and inter-canine width. One mm of COS leveling resulted in a 0.973mm increase in inter-molar width (r= -0.973, P<0.001) and a 0.926mm increase in inter-canine width (r= -0.926, P <0.001). COS leveling had a statistically significant and inverse correlation with IMPA (r = -0.439, p-value <0.001) and L1-NB (r= -0.427, p-value <0.001) changes (Table 3).

However, there was no significant correlation between the amount of COS leveling and patient's age or gender (P=0.863 and P=0.813, respectively).

Table 1. Pre & Post-treatment Curve of Spee depth, Mandibular incisor inclination, inter-canine, inter-molar widths

Variable	Pre- treatment	Post- treatment	95% CI	P-Value
Curve of Spee	2.34±0.78	1.75±0.56	.484, .688	<0.001*
IMPA (°)	91.71±2.62	94.59±2.64	-3.12, -2.63	<0.001*
LI to NB (°)	23.57±2.32	26.29±1.92	-3.27, -2.17	<0.001*
Mandibular inter-canine width (mm)	22.53±1.70	23.47±1.47	-1.14, -.717	<0.001*
Mandibular inter-molar width (mm)	42.09±2.05	43.57±1.72	-1.91, -1.05	<0.001*

* Statistically significant as a result of Paired t test.

Table 2. Comparison of pre- and post-treatment Curve of Spee depth, mandibular incisor inclination and mandibular width values in male and female subjects

Variable		Male		Female		P-Value
		Mean ± SD	95% CI	Mean ± SD	95 % CI	
Curve of Spee	pre-Treatment post-Treatment	2.35±0.814 1.72±0.53	.482, .767	2.32±0.767 1.76±0.58	.411, 0.706	<0.001 *
IMPA (°)	pre-Treatment post-Treatment	91.20±2.66 93.91±2.63	-3.32, -2.09	92.056±2.56 95.05±2.568	-3.32, -2.09	<0.001 *
LI to NB (°)	pre-Treatment post-Treatment	23.62±2.31 26.54±1.95	-3.68, -2.14	23.52±2.35 26.11±1.90	-3.38, -1.78	<0.001 *
Mandibular inter-canine width (mm)	pre-Treatment post-Treatment	22.33±1.63 23.33±1.63	-1.24, -.750	22.67±1.75 23.55±1.35	-1.21, -.55	<0.001 *
Mandibular inter-molar width (mm)	pre-Treatment post-Treatment	42.04±2.17 43.45±1.55	-2.21, -.620	42.11±1.99 43.64±1.840	-2.03, -1.01	<0.001 *

** Statistically significant as a result of Paired t test.

Table 3. Pearson Correlation between Curve of Spee and different variables

Variable	Pearson Correlation Coefficient (r)	P-Value
Curve of Spee and Inter-molar width	-0.973	<0.001***
Curve of Spee and Inter-canine width	-0.926	<0.001***
Curve of Spee and IMPA	-0.439	<0.001*
Curve of Spee and L1-NB	-0.427	<0.001*

*. P-value<0.05 indicates statistical significance

Discussion

The objective of this study was to examine alterations in mandibular incisor proclination and arch widths following the leveling of COS. Our results indicate that both mandibular incisor proclination and mandibular arch widths undergo changes after accentuation of COS.

A longitudinal study was conducted by Bishara et al. (11) to investigate the changes in maxillary and mandibular tooth size-arch length relationships from early adolescence to early adulthood. According to this study, once established in adolescence, the COS remains relatively stable. This is in accordance with a longitudinal study conducted by Carter and Macnamara (10) which revealed that COS remained stable once the second mandibular molars have erupted into occlusion. In our study, participant's mean age was 25.10±6.818 years and ranged from 13 to 40 years. The second mandibular molar had erupted into occlusion in all participants and was used as a reference point for measuring COS. Hence this suggests that COS was not influenced by age related changes during the time our patients were undergoing orthodontic treatment.

The results of the present study indicated that the age did not have a statistically significant correlation with leveling of COS (r=0.022, p=0.87). Our findings are similar to a previous study conducted by Veli et al. (12) in which they investigated COS and its relationship to vertical eruption of teeth among different malocclusion groups. They also found a statistically insignificant correlation (r=0.17) between age and COS.

In our study, the depth of COS was not influenced by patient's gender. We found a statistically weak correlation between gender and COS (r=0.032, p= 0.81). Similarly, Marshall et al. (4) conducted a longitudinal study in aims of better understanding COS development. They found that the depth of COS was not influenced by gender. Farella et al. (20) also reported a lack of correlation between COS and sexual dysmorphism. These findings are in accordance with the findings of the current study in which no significant correlation was established between COS and patient's age or gender.

A study was carried out by Krishnamurthy et al. (21) to assess and compare the radius and depth of COS in the maxillary and mandibular arch in an Indian population. The cited authors mentioned that there was no statistically significant difference in the average COS depth values between male and female individuals (p=0.77). Xu et al. (22) evaluated COS depth in the maxillary and mandibular arches of Japanese adults with a healthy permanent dentition. Their results showed that there was no statistically significant difference between average COS depth values in male (1.9 ± 0.6mm) and female (1.8 ± 0.4) patients. These findings confirm the results of our study.

A prospective study conducted by Pandis et al. (18) investigating the effects of leveling of COS on incisor proclination found that only the baseline IMPA angular measurement to be a significant predictor for COS leveling (P<0.001). They observed an increase in IMPA values and after COS leveling (92.30 ± 6.8 versus 96.80 ± 7.6, P<0.001). This is consistent with our findings indicating an increase in IMPA (from 91.74±2.62 to 94.59±2.64) and L1-NB (from 23.57±2.32 to 26.29±1.92) as COS was levelled. However, Pandis et al. (18) did not record any changes in the mandibular arch widths. Our study revealed that the leveling of COS has a high significant inverse correlation with arch width values. Our study revealed that a 1mm reduction of COS depth resulted in a 0.973mm increase in inter-molar width (r=-0.973, P<0.001) and a 0.92mm increase in inter-canine width. (r=-0.926, P<0.001).

Our study also demonstrated that the increase in mandibular arch width values secondary to COS flattening was more pronounced in the inter-molar region (0.97mm) compared to the inter-canine region (0.92mm). This can be attributed to different muscular forces acting in these two areas. A study conducted by Sadeghian (23) revealed that the thickness and functional capacity of the masseter muscle influence the mandibular inter-canine width. Similarly, facial muscles such as levator anguli oris, orbicularis oris and mentalis muscle may also have a restrictive effect on the mandibular inter-canine width (24). This finding can serve as a reference for clinicians in the strategic planning of non-extraction therapy, as this expansion has the potential to create additional space in crowded arches.

In 2006. Ahmed et al. (14) conducted a quasi-experimental study to determine the additional space required for COS leveling in the mandibular arch using continuous archwire mechanics. In their study, the COS depth and arch length was measured on 40 pre-treatment and post-treatment plaster models with the help of a sharpened Boley gauge. They claimed that the notion that 1mm of arch circumference is necessary to level 1mm of the COS was only an overestimation. Moreover, they found a low degree of correlation between COS and mandibular incisors proclination of (r=-0.14, P <0.001). However, our study suggested that COS flattening had a moderately significant inverse relationship with IMPA (r=-0.439, P <0.001) and L1-NB (r=-0.427, P<0.001).

Besides the variables included in our study, numerous other significant factors could influence changes in COS and mandibular arch widths. Among these factors are variations in facial heights and the type of malocclusion. A short facial configuration is associated with greater electromyographic activity compared to a long facial configuration and hence the variation in muscular activity amongst individuals may affect the resulting change in COS and mandibular arch widths (23). Similarly, individuals with Class III malocclusion have a wider lower jaw as compared to Class I individuals. Similarly, mandibular inter-canine width is less in Class I malocclusion than in Class II div 2 malocclusions (24). As a result, additional research should be conducted, with consideration given to these crucial factors. Furthermore, measures should be implemented to mitigate errors stemming from operators during the measurement calculations and angle acquisitions thus preventing inaccuracies.

Our study showed that leveling of COS had significant effects on incisor proclination and mandibular arch width changes. Clinicians should consider this during space analysis while developing different treatment plans since this increase in lower incisor proclination can be a favorable or non-favorable treatment outcome depending on the patient's dentition and malocclusion. Moreover, care must be taken while executing a non-extraction treatment plan to correct crowded arches in order to avoid relapse due to instability, gingival recession, bone loss and unfavorable aesthetic outcomes.

Conclusion

COS is not influenced by age or gender. Leveling of COS results in increased values of mandibular incisor proclination expressed as increased IMPA and L1-NB values. Flattening of COS is also associated with increased inter-canine and inter-molar widths. This change is more prominent in the inter-molar region than the inter-canine region. One-millimeter leveling of COS leads to 0.97mm increase in inter-molar width and 0.92mm increase in inter-canine width.

These findings can enable orthodontists to devise an accurate and successful treatment plan and also provides a guideline on adopting an approach towards COS leveling according to every patient's individual needs and demands.

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