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# Effects of levelling of the curve of Spee on the proclination of mandibular incisors and expansion of dental arches: a prospective clinical trial

Nikolaos Pandis,* Argy Polychronopoulou,† Iosif Sifakakis,+ Margarita Makou+ and Theodore Eliades±

Private practice, Corfu,* Departments of Community and Preventive Dentistry† and Orthodontics,+ School of Dentistry, University of Athens and the Department of Orthodontics, School of Dentistry, Aristotle University of Thessaloniki,± Greece

*Objectives:* To investigate the effects of levelling the curve of Spee (COS) on the inclination of the mandibular incisors and the width of the mandibular arch.
*Methods:* Fifty patients, 10–18 years of age, were selected using the following inclusion criteria: nonextraction treatment in the mandibular arch; eruption of all mandibular teeth; no spaces in the mandibular arch; no crowding in the posterior mandibular segments; a mandibular irregularity index greater than 2.5. The depth of the COS, the amount of crowding of the mandibular anterior dentition and the intercanine and intermolar widths were measured on standardised photographs of the casts. The inclinations of the mandibular incisors were measured on cephalometric radiographs. The paired *t*-test was used to analyse changes in the intercanine and intermolar widths and incisor inclinations before and after treatment, whilst the Wilcoxon signed ranks test was used to examine changes in the COS with treatment. The data were further analysed with a regression analysis to determine the measurements that predicted a reduction of the curve of Spee at the 5 per cent level of significance.
*Results:* The COS showed a median decrease of 0.9 mm, with 50 per cent of the cases ranging between 0.4 mm and 1.4 mm. The sole predictor of curve flattening was the lower incisor to mandibular plane angle.
*Conclusions:* The COS is mainly 'flattened' by proclining the mandibular incisors. For 1 mm of levelling the mandibular incisors were proclined 4 degrees, without increasing arch width.
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Nikolaos Pandis: npandis@yahoo.com
Argy Polychronolpoulou: argypoly@dent.uoa.gr
Iosif Sifakakis: isifak@gmail.gr
Margarita Makou: mmakou@dent.uoa.gr
Theodore Eliades: teliades@ath.forthnet.gr

## Introduction

The curve of Spee (COS) describes the curved plane formed by the tips of the buccal cusps of the mandibular dentition, and it is defined as the distance from the deepest point on the mandibular arch to the line connecting the tip of the mesio-buccal cusp of the lower second molar and the incisal edge of the most extruded incisor.[1] This curve was first reported to occur in the dentitions of mammals other than man and was first applied to the human dentition by Ferdinand Graf von Spee in 1890.[2]

The COS is flatter in deciduous dentitions than in adult dentitions and develops with the eruption of the mandibular first permanent molars and incisors.[3,4] Once established it remains relatively stable.[5,6] Differences in the times of eruption of the mandibular permanent teeth as well as variations in skeletal morphology, sagittal jaw relationship and incisor occlusion may affect the depth of the COS.[4,7,8] An increased curve of Spee before treatment has been associated with a low Frankfort-mandibular plane angle, deep overbite, increased overjet and Class

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Table I. Demographic and clinical characteristics of the subjects.

| Variable | | Mean ± SD (Per cent) |
|---|---|---|
| Age (years) | | 13.8 ± 1.3 |
| Gender | Male | 10 (20.0) |
| | Female | 40 (80.0) |
| | Total | 50 |
| Crowding (Irregularity index) | | 5.6 ± 2.3 |
| Crowding | Moderate (<5.5 mm) | 25 (50.0) |
| | Severe (>5.5 mm) | 25 (50.0) |
| Angle Class | I | 30 (60.0) |
| | II | 18 (36.0) |
| | III | 2 (4.0) |
| Mean treatment time | | 2.75 ± 0.84 |

Table II. Age distribution of the subjects.

| Age | N | (Per cent) |
|---|---|---|
| 10 | 1 | (2) |
| 12 | 4 | (8) |
| 13 | 18 | (36) |
| 14 | 13 | (26) |
| 15 | 10 | (20) |
| 16 | 3 | (6) |
| 18 | 1 | (2) |

II molar malocclusion, but no significant gender differences have been identified.[9]

The rationale behind the traditional concept of levelling the COS is somewhat obscure.[10] It probably facilitated early attempts at deep overbite correction before effective intrusion mechanics were available.[10] Andrews believed that a deep COS may make it almost impossible to achieve a Class I canine relationship and he associated the COS with post-treatment relapse. He concluded that flattening the COS should be an orthodontic treatment goal, even though not all normal occlusions have flat occlusal planes.[11] A deep curve of Spee may also result in occlusal interferences during mandibular function.[12]

There are two types of COS: in the first one, which is more common in cases requiring extractions, the posterior teeth are mesially inclined and they require space for uprighting.[10] In the second type of COS, no additional space is needed since the posterior axial inclinations are normal. In any case, levelling of the curve of Spee by controlled incisor intrusion and/or molar tip-back does not affect the amount of space required.[13,14] Some authors reported a linear relationship between the depth of the curve and the space required for levelling,[14-16] but others have concluded that the relationship is nonlinear and that a number of factors affect this relationship, including the site of registration of the arch circumference and the arch form.[17]

An additional factor, which can affect both the mandibular arch perimeter and arch space, is arch expansion. Steiner and Ricketts have proposed that 1 mm of lower incisor advancement produces 2 mm of arch length.[18,19] Also, 1 mm of canine expansion produces 1 mm of arch space, 1 mm of molar expansion results in only 0.25 mm increase in arch length and 2 mm per side of arch length is gained by molar uprighting.[18] Germane et al.,[20] used a mathematical model to demonstrate that a 5 mm increase in arch length required approximately 5 mm of lateral expansion or 4 mm of incisor advancement. It was also discovered that wide dental arches produce more arch length per millimetre of expansion compared to narrow arches.[20]

Currently, there is a lack of evidence of the extent of proclination of mandibular incisors and the expansion of the mandibular dental arch associated with levelling of the curve of Spee with a straight-wire appliance. Therefore, the objective of this prospective study was to investigate the effects of levelling the curve of Spee on the proclination of mandibular incisors and dental arch expansion.

## *Sample and methods*

Fifty patients, 10–18 years of age, were included in this prospective study. The participants were selected from a large pool of patients using the following inclusion criteria: nonextraction treatment in the mandible; eruption of all mandibular teeth; no spaces in the mandibular arch; no crowding in the posterior mandibular segments; a mandibular irregularity index greater than 2.5. The basic demographic and clinical characteristics of the sample are shown in Table I. Table II depicts distribution of the patients in each age group.

**Table III.** Cephalometric and cast characteristics at baseline and after treatment in all subjects (N = 50).

| Measurement | Baseline Mean ± SD | After treatment Mean ± SD | *p* |
|---|---|---|---|
| Incisor inclination | | | |
| L1-MP (degrees) | 92.3 ± 6.8 | 96.8 ± 7.6 | $<10^{-3}$ |
| L1-NB (degrees) | 25.1 ± 5.9 | 29.8 ± 5.9 | $<10^{-3}$ |
| L1-APog (degrees) | 23.5 ± 4.6 | 28.8 ± 4.6 | $<10^{-3}$ |
| Intercanine width (mm) | 25.4 ± 1.8 | 27.1 ± 1.3 | $<10^{-3}$ |
| Intermolar width (mm) | 44.1 ± 2.6 | 45.8 ± 1.9 | $<10^{-3}$ |
| Spee curve (mm) | 2.0 ± 0.5 | 1.0 ± 0.4 | $<10^{-3+}$ |

L1-MP: Mandibular incisor to mandibular plane
L1-NB: Mandibular incisor to nasion-point B line
L1-APog: Mandibular incisor to point A-pogonion line
*p* value for comparison of baseline and post-treatment measurements based on paired *t*-test
+*p* value for comparison of baseline and post-treatment measurements based on the Wilcoxon signed rank test

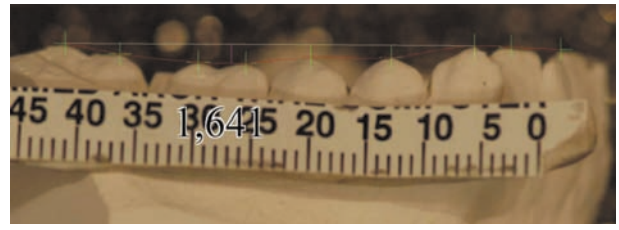



**Figure 1.** The depth of the COS was measured on digital images of the initial and final models.

All patients were bonded with a 0.022 inch slot edgewise appliance and the lower arch was levelled using a straight-wire appliance. The wire sequence was as follows: 0.014 or 0.016 ideal form Sentalloy (GAC, Central Islip, NY, USA), followed by 0.020 inch ideal form Sentalloy, 0.020 inch stainless steel wire and 0.018 x 0.025 inch stainless steel wire. Brackets were bonded at a standard height on each tooth using a bracket-positioning gauge (Ormco, Glendora, CA, USA).

Bracket bonding, archwire placement and all treatment stages were performed by the first author. Complete records were obtained before and at the end of treatment, and the amount of crowding of the mandibular anterior teeth was assessed on dental casts using the irregularity index, measured with a fine-tip digital caliper, (Mitutoyo Digimatic NTD12-6" C, Mitutoyo Corporation, Japan). Changes in the intercanine and intermolar widths were also measured on the dental casts using the cusp tips of the lower canines and the central grooves in the lower molars as reference points. The same archwire sequence was used for all subjects, and all subjects were recalled at 4–8 week intervals.

Pre- and post-treatment lateral cephalograms were traced by the same person. The inclinations of the mandibular incisors were assessed with the following angular measurements: lower incisor to mandibular plane (L1-MP); lower incisor to N-B line (L1-NB); and lower incisor to the A-Pog line (L1-APog). The COS was measured on standardised pre- and post-treatment photographs of the casts. Both sides of the models were photographed (Figure 1). The resultant digital images were entered into a cephalometric software programme (Viewbox 4.0, Dhal, Greece) and the depth of the COS was measured using the second molars and incisors as reference points. The means of the right and left side measurements were used in all subsequent calculations. The radiographs and the models were measured in a random order to blind the investigator and reduce observer bias.

To assess the intra-examiner reliability, seven models and seven cephalometric radiographs were randomly selected from the records. The radiographs were re-traced and the measurements repeated. Additionally, the intercanine and intermolar widths were remeasured on the casts. The reproducibility of the measurements was investigated with a paired *t*-test analysis for each variable. The analysis revealed no statistical significance between the first and second measurements ($p > 0.05$).

Descriptive statistics for the study sample, clinical characteristics, cast and cephalometric data were calculated. Paired *t*-tests were used to analyse changes in intercanine and intermolar widths and incisor inclinations before and after treatment, and the Wilcoxon signed rank test was used to compare the change in the COS before and after treatment. A regression analysis determined the characteristics/measurements that could be used to predict a reduction in the COS. Incisor inclination, intercanine width, intermolar width and the clinical and demographic characteristics were used in a multiple median regression model and non-significant variables were deleted by backward elimination (Deletion criterion, $p > 0.05$). A $p < 0.05$ was considered to be statistically significant.

All the analyses were conducted with the STATA 10.1 statistical package (StataCorp LP, Houston, TX, USA).

## Results

Table III gives the cephalometric and cast characteristics at baseline and after treatment in the subjects. As shown, the inclinations of the incisors and the intercanine and intermolar widths increased. The COS showed a median decrease of 0.9 mm, with 50 per cent of the cases ranging between 0.4 mm and 1.4 mm and a slight expansion of the buccal segments (Mean value: 1.7 mm). On average, a 4 degree proclination of the mandibular incisors resulted in 1 mm levelling in the COS. In the regression analysis only the baseline L1-MP angular measurement was found to be a significant predictor of the COS levelling ($p < 0.01$). The data for this finding are not shown.

## Discussion

Levelling of the COS is accomplished by molar uprighting, premolar eruption, incisor intrusion and incisor flaring or a combination of the above.[21] It seems that expansion may generate arch space in crowded arches, however, most levelling of the COS with a straight-wire appliance was accomplished by the extrusion of the premolars.[22] In agreement with a recent study, which showed a marginally significant post-treatment increase in the mandibular intercanine width in Class II division 1 deep bite cases, we found a small, but insignificant, increase in arch width.[23] The authors attributed their finding to normal physiologic changes that occur with increasing age.[23]

We found that levelling of the COS with a straight-wire appliance correlated well with proclination of the mandibular incisors measured as an increase in the mandibular incisor to MP line angle. Whilst other changes, such as an increase in both the intercanine and intermolar widths, accompanied levelling of the curve, they were found to be coincidental and not correlated with the actual levelling of the mandibular arch.

Although many studies evaluating the amount of space required to correct 1 mm of the COS have indicated that the relationship is not one-to-one, some authors have ignored their own evidence and proposed formulae to 'accurately' predict the space required to level the COS.[14-16] For example, Baldridge suggested the following formula for the accurate prediction of the required space Y = 0.488 X - .51, where Y = arch length differential in millimetres, X = sum of right and left side maximum depths of the COS in millimetres.[15] Similar formulae have been developed by Garcia (Y = 0.657 X + 1.34) and Braun (Y = 0.2462 X - 0.1723).[14,16] On the other hand, Germaine et al. found that the relation between the levelling of the COS and the space required did not follow a linear relationship and it was dependent on arch form and the depth of the COS.[22] They also showed that under most circumstances, less than 1 mm of space was required to level 1 mm of Spee.[17]

In crowded mandibular arches with a deep COS, the space required to level the curve should be considered in the treatment planning and may indicate a need for extractions. A case with 5 mm of crowding with a flat COS may be treated differently from a case with similar crowding, but with a 3 mm of COS, because proclination of mandibular incisors in the latter case could predispose the incisors to periodontal complications. In the opinion of one author the most effective means of alleviating crowding is combined incisor proclination and canine expansion.[20]

There is no general agreement as to the most appropriate biomechanical principles that should be used to accomplish stable, long-term levelling of the mandibular arch. There is no difference in the relapse of a corrected COS between extraction and non-extraction cases,[21,24] although in 16 per cent of cases the return of the COS was accompanied by an increase in the overbite.[21] Recent evidence suggests that the amount of relapse of the COS is not correlated with the initial depth of the curve.[23,25]

Relapse in the COS does not appear to be correlated with degree of the COS levelling during treatment. Some investigators consider that there is a higher incidence and magnitude of COS relapse if the COS is not completely reduced during treatment.[23,26] But the evidence is by no means clear-cut: De Praeter et al. reported there was no such correlation between the degree of levelling and relapse.[25] There is also some evidence that the contrary may be true: the more the COS is levelled during treatment the more it will relapse after treatment.[21,22] The explanation of these conflicting results lies in the differences between these studies, in particular the axial inclinations of the posterior teeth and the mechanisms of arch levelling.

Indiscriminate levelling in the mandibular arch can produce undesirable side effects, including posterior

rotation of the mandible. Building in some occlusal curvature could be desirable for both aesthetics and function.[10] A recent study concluded that a curve depth of 1.9 mm at the end of the treatment might result in higher stability, since these cases were associated with the least amount of post-treatment change.[24] Moreover, uncontrolled arch levelling with continuous archwires containing a reverse COS should be avoided, especially beyond the stage at which the occlusal plane is flat. After this stage, these wires produce excessive incisor tipping resulting from intrusive forces at the incisor brackets.[14,27] Further investigation is required of COS levelling in different facial types and its effect on mandibular rotation.

## Conclusion

Flattening of the COS is mostly achieved by proclination of the mandibular incisors. On average, a 4 degree proclination of the mandibular incisors results in 1 mm levelling of the COS. Only the L1-MP angular measurement was found to be a significant predictor of the COS levelling.

## Corresponding author

Dr Theodore Eliades
57 Agnoston Hiroon Str
Nea Ionia GR-14231
Greece
Email: teliades@ath.forthnet.gr

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