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Miodrag Marjanović[1], Ana Marija Miličević[2], Luka Šimunović[2], Tadeja Blagec[2], Marina Lapter Varga[3]

Depth of Curve of Spee in Relation to Craniofacial and Dental Morphology

Povezanost dubine Speeove krivulje s kraniofacijalnom i dentalnom morfologijom

[1] Health Center Karlovac, Karlovac, Croatia
Dom zdravlja Karlovac, Karlovac, Hrvatska
[2] Research and Teaching Assistant, Department of Orthodontics, University of Zagreb School of Dental Medicine, Zagreb, Croatia
Sveučilište u Zagrebu Stomatološki fakultet, Zavod za ortodonciju, Zagreb, Hrvatska
[3] Professor, Department of Orthodontics, University of Zagreb School of Dental Medicine, Zagreb, Croatia
Sveučilište u Zagrebu Stomatološki fakultet, Zavod za ortodonciju, Zagreb, Hrvatska

Abstract

Objectives: To quantify the depth of the Curve of Spee (CoS) in untreated orthodontic patients, evaluate its variations across Angle classifications, and identify its skeletal and dental morphological correlates. **Materials and Methods:** This retrospective study analyzed digital intraoral scans and lateral cephalograms of 240 untreated orthodontic patients (age range: 13–17 years). Subjects were categorized into four groups: Angle Class I, Class II/1, Class II/2, and Class III. CoS depth was measured using OrthoCAD, while skeletal and dental variables were assessed via AX.Ceph software. Statistical significance was determined using one-way ANOVA with Tukey's post-hoc tests, Pearson's correlation coefficients, and multiple linear regression analysis to identify primary predictors of CoS depth. **Results:** The mean CoS depth was 2.18 mm. Significant intergroup differences were observed, with the greatest depth recorded in Class II/2 (2.49 mm) and the shallowest in Class III (1.82 mm). CoS depth demonstrated significant positive correlations with overbite, overjet, ANB angle and Wits appraisal. Conversely, an inverse relationship was found with vertical skeletal parameters. A multivariate regression analysis identified overbite and sagittal skeletal indicators as the most relevant predictors of CoS depth. **Conclusion:** The depth of the CoS is critically influenced by sagittal skeletal discrepancies and incisal relationship (overbite), with vertical craniofacial morphology playing a secondary role. These findings highlight its relevance in orthodontic diagnosis and treatment planning. And the need for the individualized mechanics for CoS leveling based on the patient's specific skeletal and dental phenotype.

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Address for correspondence
Ana Marija Miličević, DMD
University of Zagreb School of Dental Medicine
Department of Orthodontics
Gundulićeva 5, 10000 Zagreb
Croatia
Phone: +385 1 4802 117
amilicevic@sfzg.unizg.hr

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Miodrag Marjanović: https://orcid.org/0009-0006-1692-4584
Ana Marija Miličević: https://orcid.org/0009-0008-5488-6915
Luka Šimunović: https://orcid.org/0000-0003-2848-6041
Tadeja Blagec: https://orcid.org/0000-0001-6096-6411
Marina Lapter Varga: https://orcid.org/0000-0003-2413-9122

Introduction

In the lateral view, the occlusal plane of the adult human dentition exhibits a characteristic superior concavity. In the mandibular dental arch, this curvature extends from the posterior teeth toward the incisors, forming a distinct anteroposterior curve. This specific spatial and geometric arrangement was first described in 1890 by Ferdinand Graf von Spee. Based on the analysis of 120 skulls with significant attrition, he defined the occlusal line as part of an imaginary cylindrical surface tangent to the anterior border of the mandibular condyle, the occlusal surfaces of the second molars, and the incisal edges of the mandibular incisors. This anatomical and functional curvature is widely recognized as the Curve of Spee (CoS) (1).

The precise functional role of this curvature has not yet been fully understood. Nevertheless, mastication, as a fun-

Uvod

U sagitalnoj dimenziji okluzijska ravnina trajne denticije pokazuje određeni stupanj zakrivljenosti, odnosno konkaviteta. U donjem zubnom luku taj anteroposteriorni konkavitet proteže se od stražnjih zuba do sjekutića. Takav specifičan prostorni raspored zuba prvi je 1890. godine opisao Ferdinand Graf von Spee. Na temelju analize 120 lubanja sa značajnim stupnjem trošenja zuba definirao je okluzijsku liniju kao dio zamišljene cilindrične plohe koja dodiruje prednji rub kondila donje čeljusti, okluzijsku plohu drugih kutnjaka i incizalne bridove donjih sjekutića. Ta anatomska i funkcionalna zakrivljenost danas je općeprihvaćena pod nazivom Speeova krivulja (Curve of Spee, CoS) (1).

Točna funkcija Speeove krivulje još nije potpuno razjašnjena. No žvakanje kao temeljna funkcija stomatognatoga sustava uvelike ovisi o ravnoteži između sila drobljenja i smi-

damental function of the maxillofacial system, largely depends on the balance between crushing and shearing forces among the teeth. It is hypothesized that the CoS performs a critical biomechanical role by optimizing force vectors in the posterior segment, thereby increasing the efficiency of food processing. Consequently, the transmission and distribution of occlusal forces during mastication are improved, suggesting that the CoS, in addition to its morphological significance, also has an important mechanical function (2, 3).

The understanding of the etiology and development of the CoS remains limited, and available evidence suggests that it is a multifactorial process. Recent evidence indicates that its formation results from a complex interaction between craniofacial growth, tooth eruption and the functional maturation of the neuromuscular system. Furthermore, the sagittal and vertical position of the mandible relative to the cranial base represents a key variable in its development (4,5). The CoS is also present in various forms in other mammals, supporting its phylogenetic and functional basis (6).

Furthermore, Andrews defined six fundamental characteristics of normal occlusion and demonstrated that, in subjects with ideal occlusion, the CoS was either completely flat or only slightly defined. He reported that optimal tooth contact occurs when the occlusal plane is relatively flat. Accordingly, leveling the occlusal plane has become a primary therapeutic objective in contemporary orthodontic practice (6).

Despite the lack of a standardized consensus regarding leveling protocols, this procedure remains a routine component of orthodontic treatment. This has prompted numerous studies aimed at analyzing its correlations with various dentoalveolar and skeletal parameters (7, 8, 9, 10, 11).

Given that previous studies on the relationship between the CoS and craniofacial morphology have shown inconsistent and sometimes contradictory results, further analyses are needed to clarify these associations. Therefore, this study aimed to determine the average depth of the CoS in patients starting orthodontic treatment, examine its relationship with Angle classification, and analyze its association with various dental and skeletal parameters.

Materials and Methods

This cross-sectional retrospective study utilized digital intraoral scans (iTero Element 2, Align Technology, San Jose, CA, USA) and lateral cephalometric radiographs obtained from the orthodontic database of the Department of Orthodontics, University Hospital Center Zagreb. A total of 240 subjects (age range: 13–17 years) were enrolled in the study based on the following inclusion criteria: presence of complete permanent dentition with all teeth in occlusal contact, absence of significant dental crowding and no history of prior orthodontic treatment. These criteria were established to ensure sample homogeneity and to eliminate confounding variables that could potentially affect dental arch morphology. The sample was divided according to Angle classification into four cohorts: Class I, Class II/1, Class II/2, and Class III, based on both clinical examination and cephalometric analysis. Digital models were analyzed using OrthoCad soft-

canja koje djeluju među zubima. Pretpostavlja se da je Speeova krivulja biomehanički važna jer optimizira vektore sila u stražnjem segmentu zubnoga luka, čime povećava učinkovitost usitnjavanja hrane. Posljedično se poboljšavaju prijenos i raspodjela okluzijskih sila tijekom mastikacije, što upućuje na to da Speeova krivulja, osim morfološkog značenja, ima i važnu mehaničku funkciju (2, 3).

Razumijevanje razvoja Speeove krivulje još je ograničeno, a dostupni dokazi upućuju na to da je riječ o multifaktorijalnom procesu. Novija istraživanja pokazuju da njezino formiranje proizlazi iz složene interakcije kraniofacijalnoga rasta, nicanja zuba i funkcionalnog sazrijevanja neuromuskularnoga sustava. Nadalje, sagitalni i vertikalni položaj mandibule u odnosu prema bazi lubanje jedna je od ključnih varijabli u njezinu razvoju (4, 5). Speeovu krivulju u različitim oblicima imaju i drugi sisavci, što dodatno podupire njezinu filogenetsku i funkcionalnu važnost (6).

Nadalje, Andrews je definirao šest temeljnih obilježja normalne okluzije te pokazao da je kod ispitanika s idealnom okluzijom Speeova krivulja bila potpuno ravna ili tek blago konkavna. Zaključio je da se optimalni kontakti između zuba ostvaruju kada je okluzijska ravnina razmjerno ravna. Sukladno tomu, izravnavanje Speeove krivulje postalo je jedan od osnovnih terapijskih ciljeva suvremene ortodontske terapije (6).

Iako nema standardiziranog konsenzusa o protokolima njezina izravnavanja, taj je postupak i dalje rutinski dio ortodontske terapije. Upravo je to potaknulo autore mnogobrojnih istraživanja da se usmjere na analizu povezanosti Speeove krivulje s različitim dentoalveolarnim i skeletnim parametrima (7 – 11).

Budući da su dosadašnja istraživanja o odnosu između Speeove krivulje i kraniofacijalne morfologije pokazala nedosljedne rezultate, a katkad i oprečne, potrebna su daljnja istraživanja kako bi se te povezanosti razjasnile. Zato je svrha ovog istraživanja bila ispitanicima odrediti prosječnu dubinu Speeove krivulje na početku ortodontske terapije te istražiti njezinu povezanost s Angleovom klasifikacijom malokluzija i različitim dentalnim i skeletnim parametrima.

Materijali i metode

U ovom presječnom retrospektivnom istraživanju korišteni su digitalni intraoralni skenovi (iTero Element 2, Align Technology, San Jose, CA, SAD) i lateralne kefalometrijske snimke prikupljene iz ortodontske baze podataka Zavoda za ortodonciju Kliničkoga bolničkog centra Zagreb. U istraživanje je bilo uključeno ukupno 240 ispitanika u dobi od 13 do 17 godina, a odabrani su prema sljedećim kriterijima: potpuno iznikla trajna denticija sa svim zubima u okluzalnom kontaktu, odsutnost izražene zbijenosti zuba te izostanak ranije provedenoga ortodontskog liječenja. Navedeni kriteriji primijenjeni su da bi se osigurala homogenost uzorka i isključili čimbenici koji bi mogli utjecati na morfologiju zubnih lukova.

Ispitanici su, na temelju kliničkoga pregleda i kefalometrijske analize, razvrstani u četiri skupine prema Angleovoj klasifikaciji: klasa I, klasa II/1, klasa II/2 i klasa III. Digitalni

ware (Align Technology, Inc.) for gnathometric assessment. Cephalometric analysis of the radiographs was performed using AX.Ceph software (Audax LLC, Slovenia) to evaluate sagittal and vertical skeletal parameters.

The depth of the CoS was defined as the perpendicular distance between the deepest point of the mandibular dental arch and a reference line connecting the tip of the incisal edge of the mandibular incisor with the tip of the distal cusp of the most posterior mandibular tooth. Measurements were performed separately on the left and right sides of the dental arch, and their arithmetic mean was used for statistical analysis (Figure 1).

The study was approved by the Ethics Committee of the University Hospital Centre Zagreb (approval number 02/013 AG).

modeli analizirani su u programu OrthoCad (Align Technology, Inc.) radi gnatometrijske analize, a kefalometrijska analiza lateralnih snimaka provedena je u programu AX.Ceph (Audax d.o.o., Slovenija) sa svrhom procjene sagitalnih i vertikalnih skeletnih parametara.

Dubina Speeove krivulje definirana je kao okomita udaljenost između njezine najdublje točke u mandibularnome zubnom luku i referentne linije koja spaja vrh incizalnoga brida donjeg sjekutića s vrhom distalne kvržice najdistalnije smještenoga zuba u donjem zubnom luku. Mjerenja su provedena zasebno na lijevoj i desnoj strani zubnoga luka, a za statističku analizu korištena je aritmetička sredina dobivenih vrijednosti (slika 1.).

Istraživanje je odobrilo Etičko povjerenstvo Kliničkoga bolničkog centra Zagreb (broj odobrenja: 02/013 AG).

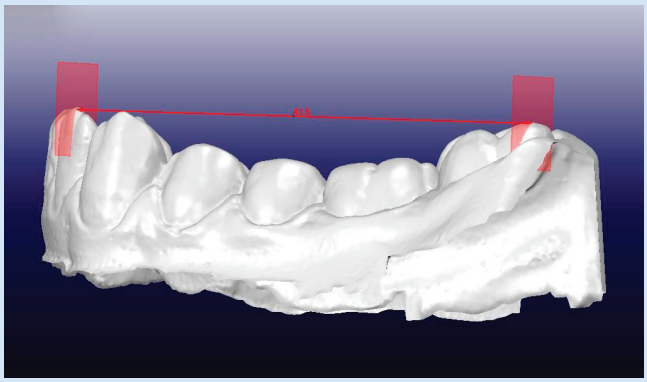

Figure 1 Measurement of the depth of the CoS using OrthoCad software (Align Technology, Inc.).
Slika 1. Mjerenje dubine Speeove krivulje u programu OrthoCad (Align Technology, Inc.)

Statistical analysis

Data were analyzed using descriptive statistics, with results expressed as mean values (M) and standard deviations (SD) for the total sample. Intergroup comparisons of the CoS depth across Comparisons across Angle classifications were conducted using a one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for multiple comparisons to identify specific intergroup differences. The association between the depth of the CoS and dental and skeletal variables was evaluated using the Pearson's correlation coefficient (r). Variables demonstrating a statistically significant correlation were subsequently entered into a multiple linear regression model, with the CoS depth serving as the dependent variable. Statistical significance for all tests was set at $p < 0.05$. All analyses were performed using IBM SPSS Statistics (version 29.0; IBM, Armonk, NY).

Statistička analiza

Podatci su analizirani primjenom deskriptivne statistike, pri čemu su za ukupni uzorak prikazani kao srednje vrijednosti (M) i standardne devijacije (SD). Usporedba dubine Speeove krivulje između skupina prema Angleovoj klasifikaciji provedena je jednosmjernom analizom varijance (ANOVA), nakon čega je primijenjen Tukeyjev post hoc test za višestruke usporedbe radi utvrđivanja razlika između pojedinih skupina.

Povezanost između dubine Speeove krivulje i dentalnih te skeletnih varijabli ispitana je Pearsonovim koeficijentom korelacije (r). Zatim su varijable koje su pokazale statistički značajnu povezanost uključene u model višestruke linearne regresije, pri čemu je dubina Speeove krivulje bila zavisna varijabla. Razina statističke značajnosti za sve analize postavljena je na $p < 0,05$. Sve statističke analize obavljene su u programu IBM SPSS Statistics (verzija 29.0; IBM, Armonk, NY, SAD).

Results

Mean values and standard deviations of the analyzed cephalometric, dentoalveolar, and occlusal parameters, according to Angle classification and for the total sample (n = 240), are presented in Table 1.

The mean depth of the CoS for the total sample was 2.18 ± 0.92 mm. When stratified by Angle classification, the most pronounced mean depth was observed in Class II/2 (2.49 ±

Rezultati

Srednje vrijednosti i standardne devijacije analiziranih kefalometrijskih, dentoalveolarnih i okluzijskih parametara, prikazane prema Angleovoj klasifikaciji i za ukupni uzorak (n = 240), nalaze se u tablici 1.

Prosječna dubina Speeove krivulje u ukupnom uzorku iznosila je 2,18 ± 0,92 mm. Prema Angleovoj klasifikaciji, najveća prosječna dubina zabilježena je u skupini klase II/2

Table 1 Mean ± SD of cephalometric, dentoalveolar, and occlusal parameters by Angle class and total sample (n = 240)
Tablica 1. Srednja vrijednost ± SD kefalometrijskih, dentoalveolarnih i okluzijskih parametara prema klasi po Angle-u i u ukupnom uzorku (n = 240)

	Class I • Klasa I		Class II/1 • Klasa II/1		Class II/2 • Klasa II/2		Class III • Klasa III		Total • Ukupno	
	Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD	Mean • Srednja vrijednost	SD
SNA	81.29	3.78	81.88	3.86	81.62	2.95	80.90	3.29	81.42	3.49
SNB	78.48	3.74	77.01	3.95	76.91	2.87	82.91	3.62	78.83	4.30
ANB	2.81	2.06	4.88	1.87	4.71	1.63	-2.01	2.88	2.60	3.51
Wits	-0.10	2.85	4.55	3.06	4.17	2.66	-6.89	3.22	0.43	5.47
N-S:Sp-Pm	8.91	3.26	8.00	2.95	9.05	2.52	9.24	3.19	8.80	3.01
N-S:M-Go	32.84	5.31	31.26	6.10	29.08	5.30	31.45	5.54	31.16	5.70
N-S-Gn	66.84	3.89	66.81	3.84	65.81	3.00	63.49	3.94	65.74	3.91
Sp-Pm:M-Go	23.95	5.36	23.25	5.57	20.02	5.35	22.21	4.93	22.36	5.48
N-S-Ar	123.47	4.84	124.75	5.13	124.57	5.49	121.73	5.51	123.63	5.36
S-Ar-Go	143.36	5.43	143.35	6.42	143.56	6.08	141.82	7.71	143.02	6.46
M-Go-Ar	126.01	6.41	123.16	6.28	120.95	6.20	127.91	5.76	124.51	6.68
NSArGoM	392.83	5.31	391.26	6.11	389.08	5.30	391.46	5.54	391.16	5.70
N-Go-M	73.51	4.06	70.88	4.49	68.76	4.46	74.10	4.66	71.81	4.89
N-Go-Ar	52.50	4.15	52.28	4.24	52.19	3.65	53.82	4.05	52.70	4.06
1:Sp-Pm	110.99	7.23	113.87	7.51	99.29	6.54	116.08	6.80	110.06	9.53
1:M-Go	91.95	5.27	96.67	5.89	93.49	6.97	84.48	6.07	91.65	7.52
1:01	133.12	10.75	126.21	8.73	147.20	9.13	137.23	8.42	135.94	11.98
1:NA	5.56	1.72	5.85	1.68	2.88	1.49	6.25	1.83	5.13	2.14
1:NB	4.75	2.04	5.19	1.57	3.44	1.58	3.78	1.66	4.29	1.85
Overbite (mm)	2.79	1.49	3.33	1.82	5.20	1.77	1.91	1.97	3.31	2.13
Overjet (mm)	3.89	1.68	7.46	2.84	4.43	0.85	-1.27	2.79	3.63	3.83
Spee (mm)	2.00	0.78	2.42	1.04	2.49	0.79	1.82	0.88	2.18	0.92

0.79 mm), followed by Class II/1 (2.42 ± 1.04 mm). In contrast, Class I subjects exhibited a mean value of 2.00 ± 0.78 mm, while the lowest mean depth was identified in the Class III subjects (1.82 ± 0.88 mm). The intergroup distribution of these values is illustrated in Figure 2.

One-way analysis of variance (ANOVA) revealed statistically significant differences in the depth of the CoS among Angle classes ($F(3,236) = 8.16$; $p < 0.001$). Subsequent Post hoc LSD analysis revealed significant differences between Class I and II/1 ($p = 0.009$), Class I and II/2 ($p = 0.002$), Class II/1 and III ($p = 0.00025$), and Class II/2 and III ($p = 0.00004$). No statistically significant differences were observed between Class II/1 and II/2 ($p = 0.65$) or between Class I and III ($p = 0.27$).

Correlation analysis showed that the depth of the CoS was significantly and moderately positively correlated with overbite ($r = 0.406$), Wits appraisal ($r = 0.367$; $p < 0.05$), overjet ($r = 0.303$; $p < 0.05$), and the ANB angle ($r = 0.228$; $p < 0.05$). In contrast, significant negative correlations were established with SNB ($r = –0.249$; $p < 0.05$), the gonial angle (M–Go–Ar) ($r = –0.209$; $p < 0.05$), and the lower anterior facial height (N–Go–Me) ($r = –0.203$; $p < 0.05$) (Table 2). All other analyzed parameters failed to demonstrate statistically significant associations with the depth of the CoS (Table 2).

The multiple linear regression analysis demonstrated statistical significance ($F(9, 230) = 10.63$, $p < 0.0001$), accounting for 29.4% of the total variance in the CoS depth ($R^2 = 0.294$, adjusted $R^2 = 0.266$). Overbite emerged as the prima-

(2,49 ± 0,79 mm), zatim u skupini klase II/1 (2,42 ± 1,04 mm). Ispitanici klase I imali su prosječnu dubinu od 2,00 ± 0,78 mm, a najmanja prosječna vrijednost ustanovljena je u skupini klase III (1,82 ± 0,88 mm). Raspodjela dubine Speeove krivulje među pojedinim Angleovim klasama prikazana je na slici 2.

Jednosmjerna analiza varijance (ANOVA) pokazala je statistički značajne razlike u dubini Speeove krivulje između Angleovih klasa [$F(3,236) = 8,16$; $p < 0,001$)]. Naknadna post hoc LSD analiza pokazala je statistički značajne razlike između klase I i klase II/1 ($p = 0,009$), klase I i klase II/2 ($p = 0,002$), klase II/1 i klase III ($p = 0,00025$) te klase II/2 i klase III ($p = 0,00004$). Statistički značajne razlike nisu utvrđene između klase II/1 i klase II/2 ($p = 0,65$), ni između klasa I i III ($p = 0,27$).

Korelacijska analiza pokazala je da je dubina Speeove krivulje bila statistički značajno i umjereno pozitivno povezana s prijeklopom ($r = 0,406$), Witsovom procjenom ($r = 0,367$; $p < 0,05$), pregrizom ($r = 0,303$; $p < 0,05$) i kutom ANB ($r = 0,228$; $p < 0,05$). Nasuprot tomu, utvrđena je statistički značajna negativna povezanost s kutom SNB ($r = –0,249$; $p < 0,05$), mandibularnim kutom (M –Go – Ar) ($r = -0,209$; $p < 0,05$) te donjom prednjom visinom lica (N – Go – Me) ($r = -0,203$; $p < 0,05$) (tablica 2.). Za sve ostale analizirane parametre nije ustanovljena statistički značajna povezanost s dubinom Speeove krivulje (tablica 2.).

Analiza višestruke linearne regresije pokazala je da je model statistički značajan [$F(9,230) = 10,63$; $p < 0,0001$] te

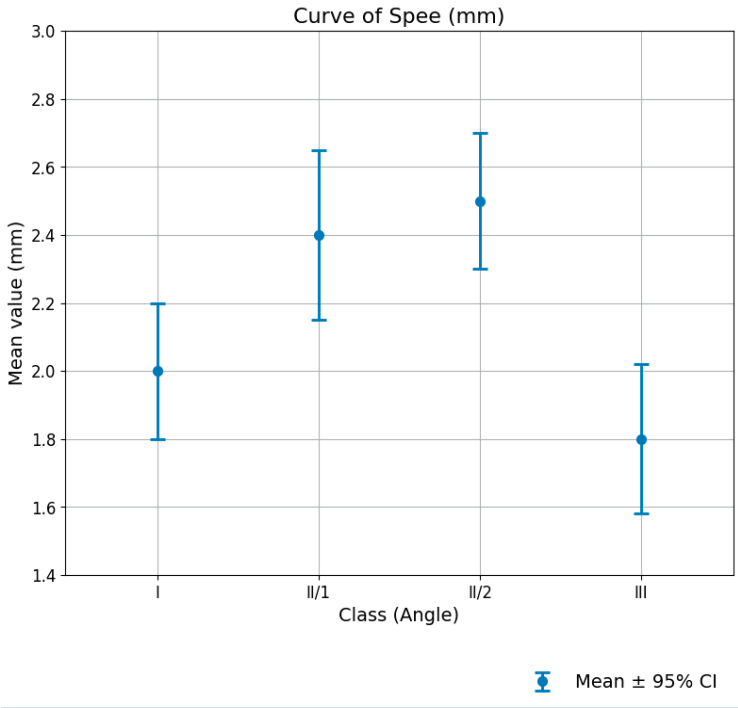

Figure 2 Mean depth of the CoS according to Angle classification
Slika 2. Prosječna dubina Speeove krivulje prema Angleovoj klasifikaciji

Table 2 Correlations between CoS depth and cephalometric and dentoalveolar parameters
Tablica 2. Korelacije između dubine Speeove krivulje (CoS) i kefalometrijskih i dentoalveolarnih parametara

Correlations • Korelacije	
Variable • Varijabla	**Spee (mm)**
SNA	-0.076685
SNB	**-0.248619**
ANB	**0.228150**
Wits	**0.366889**
N-S:Sp-Pm	-0.047511
N-S:M-Go	-0.079686
N-S-Gn	0.075501
Sp-Pm:M-Go	-0.055968
N-S-Ar	0.045495
S-Ar-Go	0.108026
M-Go-Ar	**-0.208560**
NSArGoM	-0.079433
N-Go-M	**-0.202872**
N-Go-Ar	-0.100129
1:Sp-Pm	**-0.151588**
1:M-Go	**0.130300**
1:01	0.064410
1:NA	-0.107727
1:NB	-0.078753
Overbite • Prijeklop (mm)	**0.405832**
Overjet • Pregriz (mm)	**0.302750**

Marked correlations are significant at p < .050 • Označene korelacije značajne su pri p < .050

ry predictor (β = 0.415, p < 0.0001), indicating that each 1 mm increase in overbite corresponds to a 0.178 mm increase in CoS depth. Other significant cephalometric predictors included ANB (β = -0.708, p < 0.0001), Wits appraisal (β = 0.682, p < 0.0001), N–Go–Me (β = 0.329, p = 0.0073), and M–Go–Ar (β = -0.192, p = 0.0496). Conversely, SNB, 1: Sp–Pm, 1: M–Go and overjet did not contribute significantly to the model (p > 0.05).

Discussion

This study aimed to determine the mean depth of the CoS in patients undergoing fixed orthodontic treatment and to analyze its association with Angle's classification of malocclusion, and specific dental and skeletal parameters.

According to the results of the current study, the deepest CoS was observed in Class II/2 (2. 49 ± 0.79 mm), followed by Class II/1 (2.42 ± 1.04 mm), with no significant differences between these two subgroups . The CoS was significantly deeper in Class II patients compare to those with Class I and Class III subjects. This finding is in accordance with the study by Aboulfotouh et al. (12), who also concluded that patients exhibiting Class II/2 and II/1 had the deepest CoS among other classes of malocclusion. Similar findings have

objašnjava 29,4 % ukupne varijabilnosti dubine Speeove krivulje (R^2 = 0,294; prilagođeni R^2 = 0,266). Prijeklop se pokazao najznačajnijim prediktorom (β = 0,415; p < 0,0001), pri čemu povećanje prijeklopa od 1 mm odgovara povećanju dubine Speeove krivulje za 0,178 mm.

Od ostalih važnih kefalometrijskih prediktora izdvojili su se kut ANB (β = –0,708; p < 0,0001), Witsova procjena (β = 0,682; p < 0,0001), donja prednja visina lica (N – Go – Me) (β = 0,329; p = 0,0073) te mandibularni kut (M – Go–Ar) (β = –0,192; p = 0,0496). Nasuprot tomu, kut SNB, kut 1-Pm, kut 1-Go i pregriz nisu značajno pridonijeli regresijskom modelu (p > 0,05).

Rasprava

Cilj ovog istraživanja bio je odrediti prosječnu dubinu Speeove krivulje pacijenata kojima je potrebna fiksna ortodontska terapija te analizirati njezinu povezanost s Angleovom klasifikacijom malokluzija i odabranim dentalnim i skeletnim parametrima.

Prema rezultatima ovog istraživanja, najveća dubina Speeove krivulje utvrđena je kod ispitanika s klasom II/2 (2,49 ± 0,79 mm), a slijedi ispitanik s klasom II/1 (2,42 ± 1,04 mm), pri čemu između tih dviju podskupina nije ustanovljena statistički značajna razlika. Speeova krivulja bila je također statistički značajno dublja kod ispitanika s klasom II u usporedbi s ispitanicima s klasom I i III. Taj je rezultat u skladu s istraživanjem Aboulfotouha i suradnika (12) koji su

also been described in several earlier studies (13-18). These results confirm that the radius of the CoS is shorter in patients with Class II malocclusion. Moreover, it is well known that the depth of the CoS in the lower arch is affected by the anteroposterior position of the incisors (2, 12).

Although no significant difference was observed between Angle Class I and Class III subjects in the present study, Class III individuals exhibited a flatter (less concave) occlusal curvature. Two recent studies also reported that no significant difference was observed in the depth of the curve between Class I and Class III subjects. Moreover, the curve was less concave in subjects exhibiting Class III, which is in line with the results of the current study (15, 16). In contrast, a recent meta-analysis suggests that Class I malocclusions may demonstrate a significantly deeper CoS than Class III malocclusions, highlighting a point of divergence in the current orthodontic literature (19). Regarding other evaluated parameters, the depth of the CoS exhibited a positive correlation with overbite, overjet, ANB angle, and Wits appraisal.

The association between increased overbite and CoS depth is well-documented in the literature, with studies emphasizing that an increased CoS plays a fundamental role in the etiology of deep bite malocclusions (3, 18, 20). It is known that subjects exhibiting Class II/2 usually have an increased overbite (15, 21). Hence, it was expected that in those patients, the CoS would be the deepest.

Our results further align with Halimi et al. and other investigators (20, 22, 23) who reported that CoS depth is positively correlated with both overjet and overbite. Regarding skeletal patterns, individuals with an increased ANB angle demonstrated a significantly deeper CoS compared to those with skeletal Class I relationships, which is in accordance with the results of the current study (19). Thus, the CoS is directly related to the anteroposterior position of the maxilla and mandible and the horizontal position of the condyle.

Regarding skeletal vertical parameters, the CoS in the present study exhibited a negative correlation with both the gonial angle and lower anterior facial height. It has been shown that high-angle subjects have a flatter CoS compared to low-angle patients. Skeletal deep bites are generally linked to an exaggerated CoS, whereas high-angle patients usually display open-bite characteristics or a diminished overbite, resulting in a less pronounced occlusal curvature (11, 15, 24).

The evaluation of the depth of the CoS is an important part of orthodontic diagnosis, which is related to treatment planning (13). A primary treatment objective, particularly in Class II malocclusions, is the leveling of the CoS to achieve optimal intercuspation between the maxillary and mandibular dentition (6). Moreover, flattening of the CoS will not only decrease the overbite, but will also gain extra space for the mandibular teeth, which is especially important in cases exhibiting crowding in the lower dental arch. Furthermore, as the efficiency of occlusal forces during mastication is linked to the degree of curvature, achieving a flatter CoS remains a fundamental goal for functional stability and occlusal harmony during orthodontic treatment (16).

također utvrdili da ispitanici s klasom II/2 i II/1 imaju najizraženiju dubinu Speeove krivulje u usporedbi s ostalim klasama. Slični rezultati opisani su i u nekoliko ranijih istraživanja (13 – 18). Dakle, u prethodnim studijama potvrđuje se da Speeova krivulja ima značajno izraženiji konkavitet kod pacijenata čiji je odnos kutnjaka u klasi II. Nadalje, dobro je poznato da na dubinu Speeove krivulje u donjem zubnom luku utječe anteroposteriorni položaj inciziva (2, 12).

Iako u ovom istraživanju nije utvrđena statistički značajna razlika u dubini Speeove krivulje između ispitanika s Angleovom klasom I i III, kod ispitanika s klasom III uočena je ravnija, odnosno manje konkavna Speeova krivulja. Autori dviju novijih studija također nisu ustanovili statistički značajnu razliku u dubini Speeove krivulje između ispitanika s klasom I i III. Uz to, Speeova krivulja bila je manje konkavna kod ispitanika s kutnjacima u klasi III, što je u skladu s rezultatima ovog istraživanja (15, 16). Nasuprot tomu, nedavno objavljena metaanaliza upućuje na to da ispitanici s malokluzijom klase I mogu imati statistički značajno veću dubinu Speeove krivulje u usporedbi s ispitanicima u klasi III, što je jedno od područja neslaganja u suvremenoj ortodontskoj literaturi (19). Kad je riječ o ostalim analiziranim parametrima, dubina Speeove krivulje pokazala je pozitivnu korelaciju s prijeklopom, pregrizom, kutom ANB i Witsovom analizom.

Povezanost između prijeklopa i dubine Speeove krivulje dobro je dokumentirana u literaturi, pri čemu se u mnogobrojnim istraživanjima ističe da je izraženija Speeova krivulja važna u etiologiji dubokoga zagriza (3, 18, 20). Poznato je da ispitanici s malokluzijom klase II/2 u pravilu imaju povećan prijeklop (15, 21). Zato je bilo očekivano da će upravo njihova Speeova krivulja imati najizraženiji konkavitet.

Rezultati ovog istraživanja također su u skladu s onima Halimija i suradnika te drugih autora (20, 22, 23) koji su utvrdili pozitivnu povezanost između dubine Speeove krivulje te pregriza i prijeklopa. Kad je pak riječ o skeletnim obilježjima, u jednoj recentnoj studiji ispitanici s povećanim kutom ANB imali su statistički značajno dublju Speeovu krivulju u usporedbi s ispitanicima sa skeletnom klasom I, što je u skladu s rezultatima ovog istraživanja (19). Navedeni nalazi upućuju na to da je dubina Speeove krivulje izravno povezana s anteroposteriornim odnosom maksile i mandibule te horizontalnim položajem mandibularnog kondila.

Kad je riječ o vertikalnim skeletnim parametarima, u ovom je istraživanju utvrđena negativna povezanost između dubine Speeove krivulje te mandibularnoga kuta i donje prednje visine lica. Pokazano je da ispitanici s vertiklanim načinom rasta imaju ravniju, odnosno manje konkavnu Speeovu krivulju u usporedbi s ispitanicima s horizontalnim rastom. Skeletni duboki zagriz u pravilu je povezan s izraženijom Speeovom krivuljom, a ispitanici s vertikalnim rastom najčešće pokazuju obilježja otvorenoga zagriza ili smanjenog preklopa, što rezultira manje izraženom zakrivljenošću okluzijske ravnine (11, 15, 24).

Procjena dubine Speeove krivulje važan je dio ortodontske dijagnostike jer je itekako potrebna u planiranju terapije (13). Jedan od osnovnih ciljeva ortodontske terapije, osobito u slučaju malokluzija klase II, jest izravnavanje Speeove krivulje radi postizanja optimalne interkuspidacije između zu-

Conclusion

The most pronounced CoS was observed in Class II/II, followed by Class II/1. Conversely, the flattest occlusal curvature was characteristic in Class III subjects; although no statistically significant difference in CoS depth was found between Class I and Class III groups.

In conclusion, CoS depth demonstrated a significant positive correlation with overjet, overbite, the Wits appraisal, and with the ANB angle. Furthermore, a significant negative correlation was identified between CoS depth and vertical skeletal parameters, indicating that hyperdivergent growth patterns are associated with a flatter occlusal plane.

Conflict of interest: None declared

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ba gornjega i donjega zubnog luka (6). Uz to, izravnavanje Speeove krivulje ne samo da smanjuje dubinu zagriza, nego omogućuje i dobivanje dodatnoga prostora u mandibularnome zubnom luku, što je osobito važno kod zbijenosti donjih zuba koji se pritom protrudiraju. Budući da je učinkovitost prijenosa okluzijskih sila tijekom mastikacije povezana sa stupnjem zakrivljenosti Speeove krivulje, postizanje njezina izravnavanja i dalje je jedan od temeljnih ciljeva ortodontske terapije radi osiguravanja funkcijske stabilnosti i pravilne okluzije (16).

Zaključak

Najizraženija Speeova krivulja utvrđena je kod ispitanika s klasom II/2, zatim kod onih s klasom II/1. Suprotno tomu, najplića okluzijska krivulja zabilježena je kod ispitanika s klasom III, iako između skupina s klasama I i III nije ustanovljena statistički značajna razlika u dubini Speeove krivulje.

Dubina Speeove krivulje pokazala je statistički značajnu pozitivnu povezanost s pregrizom (overjet), prijeklopom (overbite), Witsovom procjenom i kutom ANB. Nadalje, utvrđena je statistički značajna negativna povezanost između dubine Speeove krivulje i vertikalnih skeletnih parametara, što upućuje na to da su hiperdivergentni načini rasta povezani s plićom okluzijskom krivuljom.

Sukob interesa: Autori nisu bili u sukobu interesa.

Doprinosi autora: **M. M.** – konceptualizacija, prikupljanje podataka, metodologija, istraživanje; **A. M. M.** – izvorni nacrt teksta, pretraživanje literature, vizualizacija; **L. Š.** – formalna analiza, interpretacija podataka, izvorni nacrt teksta; **T. B.** – pregled i uređivanje teksta, izvorni nacrt teksta; **M. L. V.** – supervizija, validacija, vizualizacija, pregled i uređivanje teksta. Svi autori pregledali su tekst i odobrili konačnu verziju.

Sažetak

Cilj: Odrediti prosječnu dubinu Speeove krivulje na početku ortodontske terapije ispitanika te ispitati njezinu povezanost s Angleovom klasifikacijom malokluzija i različitim dentalnim i skeletnim parametrima. **Materijali i metode:** U ovo retrospektivno istraživanje bilo je uključeno 240 ispitanika (13 – 17 godina) kojima je bila potrebna fiksna ortodontska terapija. Pritom su analizirani njihovi digitalni skenovi i lateralne kefalometrijske snimke. Prema odnosu kutnjaka ispitanici su razvrstani u četiri skupine: klasa I, II/1, II/2 i klasa III prema Angleu. Dubina Speeove krivulje određena je u programu OrthoCAD, a skeletni i dentalni parametri analizirani su programom AX.Ceph. Statistička analiza uključivala je jednosmjernu analizu varijance (ANOVA) Tukeyjevim post hoc testom, Pearsonov koeficijent korelacije i višestruku linearnu regresiju radi utvrđivanja prediktora dubine Speeove krivulje. **Rezultati:** Prosječna dubina Speeove krivulje iznosila je 2,18 mm. Utvrđene su statistički značajne razlike među skupinama, pri čemu je najveća dubina zabilježena kod ispitanika s malokluzijom klase II/2 (2,49 mm), a najmanju je imao ispitanik s klasom III (1,82 mm). Dubina Speeove krivulje pokazala je značajnu pozitivnu korelaciju s preklopom, pregrizom, kutom ANB i Witsovom analizom. Suprotno tomu, ustanovljena je negativna povezanost s vertikalnim skeletnim parametrima. Višestruka regresijska analiza pokazala je da su preklop te pokazatelji sagitalnih skeletnih odnosa najvažniji prediktori dubine Speeove krivulje. **Zaključak:** Na dubinu Speeove krivulje ponajprije utječu sagitalni skeletni odnosi i odnos sjekutića, odnosno preklop, a vertikalni kraniofacijalni odnosi imaju manji utjecaj. Dobiveni rezultati potvrđuju važnost procjene Speeove krivulje u ortodontskoj dijagnostici i planiranju terapije te upućuju na potrebu individualiziranog pristupa u njezinu izravnavanju prilagođenog skeletnom i dentalnom fenotipu svakog pacijenta.

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Adresa za dopisivanje
Ana Marija Miličević, dr. med. dent.
Sveučilište u Zagrebu Stomatološki fakultet
Zavod za ortodonciju
Gundulićeva 5, 10 000 Zagreb
Hrvatska
tel: +385 1 4802 117
amilicevic@sfzg.unizg.hr

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