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IZVORNI ZNANSTVENI RAD

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Tooth Crown Dimensions among Angle Occlusion Classes in Kosovar Adolescents

Dimenzije kruna zuba kosovskih adolescenata među klasama okluzije prema Angleu

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Abstract

Objectives: To evaluate the mesiodistal (MD), buccolingual (BL), cervico-incisal (CI), the diagonal dimensions (mesiobuccal-distolingual [MBDL] and mesiolingual-distobuccal [MLDB]) of permanent teeth crowns in Kosovar adolescents. Also, the aim is to assess their relationship with Angle occlusion classes. **Materials and Methods:** 400 Kosovar adolescents aged 13–19 years took part in this cross-sectional study. The study sample comprised 216 females (54%) and 184 males (46%), classified according to Angle Class I (n = 212; 53.0%), Class II (n = 166; 41.5%), and Class III (n = 22; 5.5%). Dimensions of the crowns of permanent teeth (excluding third molars), were measured on the dental casts with a digital caliper (precision 0.01 mm). One-way ANOVA or the Kruskal-Wallis tests were used for statistical analyses ($p < 0.05$). **Results:** Significant differences between Malocclusion Classes were observed for mesiodistal (MD) and cervico-incisal (CI) dimensions in the maxillary incisors and premolars ($p < 0.05$). Class I subjects exhibited the greatest mesiodistal and cervico-incisal dimensions in the maxillary arch compared to those in Class II and III. In contrast, Class III subjects demonstrated the largest diagonal and cervico-incisal dimensions in the mandibular teeth. Buccolingual dimensions showed minimal variation across occlusion classes. **Conclusions:** Tooth crown dimensions differ significantly among Angle occlusion classes in Kosovar adolescents, with class-specific patterns most evident in mesiodistal, cervico-incisal, and diagonal measurements. These results indicate that occlusion- and population-specific odontometric data should be incorporated into orthodontic diagnosis, space analysis, and treatment planning to enhance clinical accuracy in the Kosovar population.

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Introduction

Orthodontic treatment planning requires an accurate assessment of tooth shape and size. Accurate tooth crown measurements are essential for evaluating space discrepancies, arch coordination, and treatment outcomes. The arch length, occlusal relationships, and treatment outcome prediction depend on the measurement of five odontometric parameters, which include mesio-distal (MD), bucco-lingual (BL), cervico-incisal (CI), and diagonal (MBDL and MLDB) tooth crown measurements (1-3). The clinical treatment decisions depend on tooth size variations because tooth size discrepancies cause dental crowding, occlusal problems, and affect the Bolton ratio (4-6).

Uvod

Planiranje ortodontske terapije zahtijeva preciznu procjenu oblika i veličine zuba. Točna mjerenja kruna zuba ključna su za procjenu prostornih diskrepancija, koordinaciju zubnih lukova i ishoda liječenja. Duljina zubnoga luka, okluzijski odnosi i predviđanje ishoda liječenja ovise o mjerenju pet odontometrijskih parametara koji uključuju meziodistalne (MD), bukolingvalne (BL), cervikoincizalne (CI) i dijagonalne (MBDL i MLDB) dimenzije kruna zuba (1 – 3). Kliničke odluke o liječenju ovise o varijacijama u veličini zuba jer diskrepancije u njihovoj veličini uzrokuju dentalnu zbijenost i okluzijske probleme te utječu na Boltonov omjer (4 – 6).

While odontometrics is the measurement of tooth dimensions, morphometrics describes the broader analysis of tooth shape and morphological variation. Odontometric parameters are objective descriptors of dental size and are essential for both population comparisons and clinical assessment (7).

Bolton originally developed the method to compare maxillary and mandibular teeth and to identify irregularities that alter the stability of the bite and occlusal position (1). Research following Bolton's work has demonstrated that tooth dimensions between different malocclusion types and human groups present distinct patterns (2-6). Since genetic, geographic, and environmental factors influence dental morphometric diversity, establishing population-based reference values is needed. Digital 3D models, morphometric analysis, and tooth crown morphology have revealed distinct tooth proportions among different ethnic groups and populations, which is of great clinical value. The use of odontometric and morphometric data analysis demonstrates the essential role of precise measurements in orthodontic practice (8-13). The use of digital methods has become more common, but plaster models continue to serve as the primary tool for larger population studies because they are easy to access and do not require digital technology (8-13). Tooth crown height (cervico-incisal diameter) has also been identified as a vertical component of morphological adaptation and occlusal compensation (14, 15).

Despite the increasing amount of research in various parts of the world, morphometric data remain limited for populations in Southeastern Europe, including Kosovo. Previous studies in the Kosovar population have only analyzed tooth size differences through Bolton analysis (16) or have been limited to certain tooth groups, such as a pilot study using digital 3D models to examine interarch tooth size relationships in subjects with various malocclusions (17), a recent odontometric study focusing on mesiodistal crown dimension (crown width) of mandibular canines and intercanine distance for gender differentiation (18), and a more recent CBCT-based study on sexual dimorphism in maxillary canine dimensions (19).

However, such studies are either limited to certain analytical approaches or to specific teeth and are not capable of conducting a comprehensive multidimensional assessment of tooth size. The reference values for tooth size measurements (MD, BL, CI, and diagonal (MBDL, MLDB)) in different occlusion classes are not yet available for Kosovar adolescents.

Due to differences in the morphology between populations, it is necessary to establish normative data for Kosovar adolescents so that diagnostic precision as well as treatment planning can be improved. The aim of the study was to measure and compare tooth-size dimensions of Kosovar adolescents with Angle Class I, II, and III occlusions and to hypothesize that each occlusion class would exhibit characteristic odontometric features associated with adaptive dental variations in relation to the corresponding occlusal patterns.

This study provides novel and clinically relevant data through a multidimensional analysis of tooth size in Kos-

Dok je odontometrija mjerenje dimenzija zuba, morfometrija je šira analiza oblika zuba i morfoloških varijacija. Odontometrijski parametri objektivni su pokazatelji dentalne veličine i ključni su kako za usporedbe među populacijama tako i za kliničku procjenu (7).

Bolton je izvorno razvio metodu za usporedbu maksilarnih i mandibularnih zuba te identifikaciju nepravilnosti koje mijenjaju stabilnost zagriza i okluzijski položaj (1). Istraživanja koja su slijedila poslije njegova rada pokazala su da dimenzije zuba između različitih tipova malokluzija i ljudskih skupina pokazuju različite uzorke (2 – 6). Budući da genetski, geografski i okolišni čimbenici utječu na dentalnu morfometrijsku raznolikost, potrebno je ustanoviti referentne vrijednosti specifične za populaciju. Istraživanja u kojima su primijenjeni digitalni 3D modeli, morfometrijska analiza i morfologija kruna zuba pokazala su da različite etničke skupine i specifične populacije imaju različite proporcije zuba, što je klinički veoma važno. Primjena analize odontometrijskih i morfometrijskih podataka pokazuje da su precizna mjerenja postala ključna u ortodontskoj praksi (8 – 13). Primjena digitalnih metoda sve je češća, ali gipsani modeli i dalje služe kao primarni alat u većim populacijskim istraživanjima jer su lako dostupni i ne zahtijevaju digitalnu tehnologiju (8 – 13). Visina krune zuba (cervikoincizalni promjer) također je prihvaćena kao vertikalna komponenta morfološke prilagodbe i okluzijske kompenzacije (14, 15).

Unatoč sve većem broju istraživanja provedenih u različitim dijelovima svijeta, morfometrijski podatci za populacije jugoistočne Europe, uključujući i Kosovo, i dalje su ograničeni. U dosadašnjim istraživanjima kosovske populacije analizirane su razlike u veličini zuba samo primjenom Boltonove analize (16) ili su bila ograničena na određene skupine zuba, poput pilot-istraživanja u kojemu su se primjenom digitalnih 3D modela ispitivali odnosi u veličini zuba između zubnih lukova ispitanika s različitim malokluzijama (17), zatim novijega odontometrijskog istraživanja usmjerenoga na meziodistalnu dimenziju krune mandibularnih očnjaka i interkaninu udaljenost radi razlikovanja prema spolu (18) te novijega istraživanja utemeljenoga na CBCT-u o spolnom dimorfizmu dimenzija maksilarnih očnjaka (19).

No takva su istraživanja ili ograničena na određene analitičke pristupe ili na pojedine zube te ne omogućuju sveobuhvatnu multidimenzionalnu procjenu veličine zuba. Referentne vrijednosti za mjerenja veličine zuba [MD, BL, CI i dijagonalne dimenzije (MBDL, MLDB)] u različitim klasama okluzije još nisu dostupne kosovskim adolescentima.

Zbog razlika u morfologiji među populacijama potrebno je utvrditi normativne podatke za kosovske adolescente kako bi se poboljšali dijagnostička preciznost i planiranje liječenja. Svrha ovog istraživanja bila je izmjeriti i usporediti dimenzije zuba kosovskih adolescenata s okluzijama klase I, II i III prema Angleu te postaviti hipotezu da će svaka klasa okluzije pokazivati karakteristične odontometrijske značajke povezane s adaptivnim dentalnim varijacijama u usporedbi s odgovarajućim okluzijskim obrascima.

Ovo istraživanje pruža nove i klinički relevantne podatke s multidimenzionalnom analizom veličine zuba kosovskih adolescenata različitih klasa okluzije prema Angleu, čime se

ovar adolescents across various Angle occlusion classes. Unlike previous studies that mainly focused on mesiodistal and buccolingual dimensions or Bolton ratios, this approach offers a more complete three-dimensional characterization of crown morphology. Additionally, this study presents the first population-specific reference values for several tooth dimensions in Kosovar adolescents, which can improve orthodontic diagnosis, space analysis, and treatment planning.

Materials and Methods

Study design

The study followed a cross-sectional design and was carried out from April to September 2021, and included participants from seven major cities in Kosovo (Prishtina, Prizren, Peja, Gjakova, Mitrovica, Ferizaj, and Gjilan). Dental impressions were taken from participants who were adolescents, fulfilled the inclusion criteria, and were present in primary and secondary schools. This study was performed following STROBE standards for observational studies.

Sample selection

In this study, 400 Kosovar adolescents (13–19 years, mean age: 15.7 ± 1.9 years) from stratified random sampling (n=216 females; 54% and n=184 males, 46%) were clinically diagnosed into Angle Class I (n = 212; 53.0%), Class II (n = 166; 41.5%), and Class III (n = 22; 5.5%) occlusion groups.

Sample size was calculated based on the adolescent population of Kosovo (N = 243,727) using a 95% confidence level, a 5% margin of error, and a z-score of 1.96. The minimum required sample size was estimated at 374 participants. To improve representativeness and statistical precision, the final sample included 400 adolescents.

Inclusion criteria:

- Presence of all permanent teeth except third molars;
- No previous orthodontic treatment;
- No caries, restorations, visible attrition, abrasion, incisal chipping, occlusal wear facets, trauma, or anomalies affecting the crown morphology.

Exclusion criteria:

- Congenital craniofacial anomalies or syndromes
- Severely rotated teeth or fractured crowns
- Gingival inflammation
- Gingival hypertrophy
- Gingival recession and incomplete dental eruption.

Measurements and instrumentation

Dental impressions were prepared using a Class A Type I chromatic alginate material (Kromopan, ISO 21563, Lascod S.p.A., Firenze, Italy) and immediately poured into Type III dental stone (Blue Stone; Interdent, Celje, Slovenia). On the obtained plaster models, measurements were made using a digital Vernier caliper (Mitutoyo CD-6"ASX, Japan) with a precision of 0.01 mm.

All permanent teeth, except third molars, were recorded as follows:

- Mesiodistal (MD) width, defined as the maximum distance between the mesial and distal contact points;
- Buccolingual (BL) width, representing the maximum

omogućuje potpunija trodimenzionalna karakterizacija morfologije kruna u usporedbi s dosadašnjim istraživanjima u kojima su se uglavnom koristile meziodistalne i bukolingvalne dimenzije ili Boltonovi omjeri. Uz to, u ovom su istraživanju prve referentne vrijednosti specifične za populaciju za nekoliko dimenzija zuba kod kosovskih adolescenata, što bi moglo pridonijeti poboljšanju ortodontske dijagnostike, analize prostora i planiranja liječenja u ovoj populaciji.

Materijali i metode

Dizajn istraživanja

Istraživanje je provedeno prema presječnom dizajnu od travnja do rujna 2021. godine te je obuhvaćalo sudionike iz sedam najvećih gradova na Kosovu (Priština, Prizren, Peć, Đakovica, Mitrovica, Uroševac i Gnjilane). Dentalni otisci uzeti su od adolescenata koji su ispunjavali kriterije za uključivanje i pohađali osnovne i srednje škole. Ovo istraživanje provedeno je u skladu sa standardima STROBE-a za opservacijska istraživanja.

Odabir uzorka

U ovo je istraživanje bilo uključeno 400 kosovskih adolescenata (13 – 19 godina, prosječna dob: 15,7 ± 1,9 godina) odabranih stratificiranim slučajnim uzorkovanjem (n = 216 djevojaka, 54 % i n = 184 mladića, 46 %) koji su klinički klasificirani u skupine okluzije klase I (n = 212, 53,0 %), klase II (n = 166, 41,5 %) i klase III (n = 22, 5,5 %) prema Angleu.

Veličina uzorka izračunata je na temelju populacije adolescenata na Kosovu (N = 243 727), uz razinu pouzdanosti od 95 %, marginu pogreške od 5 % i z-vrijednost od 1,96. Minimalna potrebna veličina uzorka procijenjena je na 374 sudionika. Da bi se poboljšale reprezentativnost i statistička preciznost, konačni uzorak obuhvatio je 400 adolescenata.

Kriteriji za uključivane: svi trajni zubi, osim trećih kutnjaka; bez prethodnoga ortodontskog liječenja; bez karijesa, ispuna, vidljive abrazije, atricije, okrhnuća incizalnoga ruba, okluzijskih faseta, traume ili anomalija koje utječu na morfologiju krune.

Kriteriji za isključivanje: kongenitalne kraniofacijalne anomalije ili sindromi, iznimno rotirani zubi ili frakturirane krune, gingivna upala, gingivna hipertrofija, gingivna recesija i nepotpuna erupcija zuba.

Mjerenja i instrumentacija

Dentalni otisci uzeti su alginatnim materijalom klase A tipa I u boji (Kromopan, ISO 21563, Lascod S.p.A., Firenze, Italija) i odmah izliveni u dentalnu sadru tipa III (Blue Stone; Interdent, Celje, Slovenija). Na dobivenim sadrenim modelima mjerenja su obavljena digitalnim pomičnim mjerilom (Mitutoyo CD-6"ASX, Japan) s preciznošću od 0,01 mm.

Svi trajni zubi, osim trećih kutnjaka, evidentirani su kako slijedi:

- meziodistalna (MD) širina, definirana kao najveća udaljenost između mezijalne i distalne kontaktne točke
- bukolingvalna (BL) širina koja pokazuje najveću udaljenost između bukalne i lingvalne površine

distance between the buccal and lingual surfaces;
- Cervico-incisal (CI), representing clinical crown height, measured from the gingival margin to the incisal edge or cusp tip;
- Diagonal measurements, obtained from mesiobuccal to distolingual (MBDL) and mesiolingual to distobuccal (MLDB) points of the crown (Figures 1A, 1B). For anterior teeth, MBDL was measured from the mesiolabial point to the distolingual point, whereas MLDB was measured from the mesiolingual point to the distolabial point, following the same diagonal measurement principle used for posterior teeth.

All measurements were recorded in millimeters, with two decimals (2, 7, 20).

- cervikoincizalna (CI) dimenzija koja pokazuje visinu kliničke krune mjerenu od gingivnoga ruba do incizalnoga ruba ili vrha kvržice
- dijagonalna mjerenja dobivena između meziobukalne i distolingvalne (MBDL) te meziolingvalne i distobukalne (MLDB) točke krune (slike 1. A, 1. B); za prednje zube MBDL je mjeren od meziolabijalne do distolingvalne točke, a MLDB od meziolingvalne do distolabijalne točke, prema istom načelu dijagonalnog mjerenja koje se primjenjuje za stražnje zube.

Sva mjerenja zabilježena su u milimetrima s dvjema decimalama (2, 7, 20).

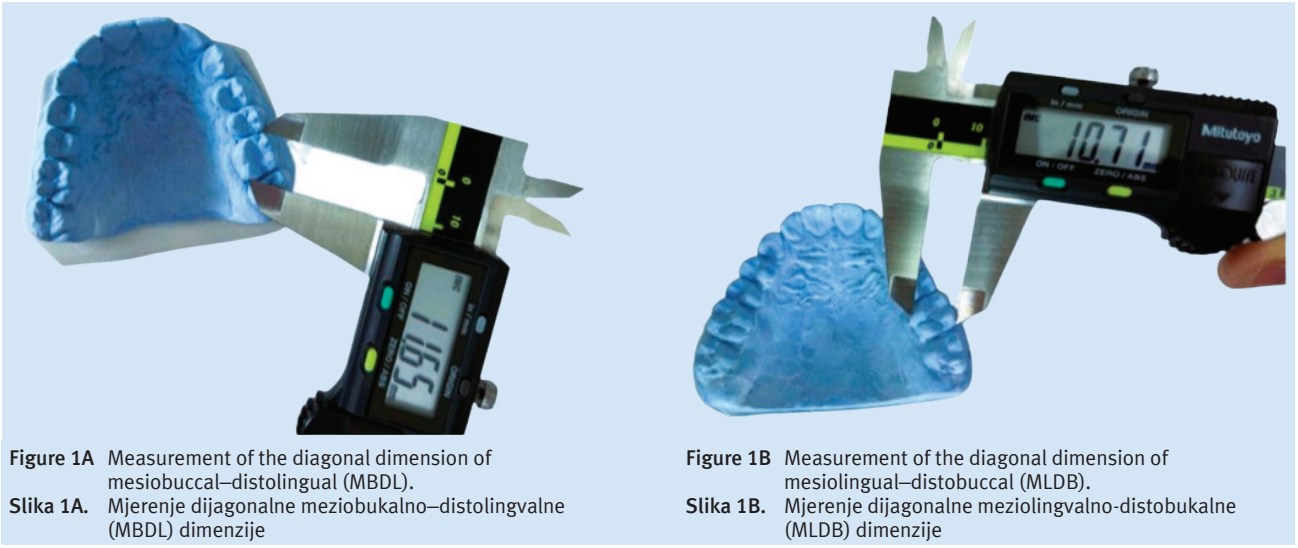

Figure 1A Measurement of the diagonal dimension of mesiobuccal–distolingual (MBDL).
Slika 1A. Mjerenje dijagonalne meziobukalno–distolingvalne (MBDL) dimenzije

Figure 1B Measurement of the diagonal dimension of mesiolingual–distobuccal (MLDB).
Slika 1B. Mjerenje dijagonalne meziolingvalno-distobukalne (MLDB) dimenzije

Reliability and reproducibility

All measurements were performed by a single calibrated examiner; therefore, only intra-examiner reliability was assessed. For the intra-examiner reliability assessment, the same examiner remeasured ten randomly selected models two weeks later.

The Dahlberg formula was used to perform the reproducibility analysis: $ME = \sqrt{\Sigma d^2/2n}$. Low mean differences and no significant variation between sessions ($p > 0.05$) were found. All ME values were below 0.25 mm, confirming excellent reproducibility.

Statistical analysis

IBM SPSS Statistics Version 27.0 (Armonk, NY: IBM Corp., USA) was used to analyze the data. Data normality was assessed using the Shapiro-Wilk test; normally distributed data were examined using a one-way ANOVA test, and non-normally distributed data were examined using a Kruskal-Wallis test. Data for all study variables are displayed as mean ± standard deviation (SD). The difference was considered as statistically significant at $p < 0.05$, and highly significant at $p < 0.01$.

The results were interpreted with caution, with emphasis on consistent inter-arch and interclass patterns rather than

Pouzdanost i reproducibilnost

Sva mjerenja obavio je jedan kalibrirani ispitivač i zato je procijenjena samo pouzdanost unutar ispitivača. Za procjenu pouzdanosti unutar ispitivača isti je ispitivač dva tjedna poslije ponovno izmjerio deset nasumično odabranih modela.

Za analizu reproducibilnosti primijenjena je Dahlbergova formula: $ME = \sqrt{\Sigma d^2/2n}$. Utvrđene su male srednje razlike i nije pronađena značajna varijacija između mjerenja u dvama terminima ($p > 0,05$). Sve vrijednosti ME-a bile su manje od 0,25 mm, što potvrđuje izvrsnu reproducibilnost.

Statistička analiza

Za analizu podataka korišten je IBM SPSS Statistics, verzija 27.0 (Armonk, NY: IBM Corp., SAD). Normalnost podataka procijenjena je Shapiro-Wilkovim testom; normalno distribuirani podatci analizirani su jednosmjernom ANOVA-om, a nenormalno distribuirani i Kruskal-Wallisovim testom. Podatci za sve varijable istraživanja prikazani su kao srednja vrijednost ± standardna devijacija (SD). Razlika se smatrala statistički značajnom pri $p < 0,05$, a visoko značajnom pri $p < 0,01$.

Budući da su provedene višestruke usporedbe među zubima i mjernim dimenzijama, rezultati su interpretirani s opre-

isolated statistically significant differences, as multiple comparisons were made across teeth and measurement dimensions.

Ethical considerations

This study followed the guidelines outlined in the Declaration of Helsinki (2013). Ethical approval was endorsed by the Ethics Committee of the School of Dental Medicine, University of Zagreb, Croatia (approval No. 05-PA-30-XXIII-1/2021) and the Education Offices in each of the seven cities.

Participants under age 18 had written informed consent provided by a parent or legal guardian, while participants aged 18 years and over gave their own written informed consent with verbal assent from all adolescent participants. All procedures followed the relevant institutional and national research standards involving human participants.

Results

Sample characteristics

The distribution of the study sample according to sex and occlusion classes groups is shown in Table 1.

zom, uz naglasak na dosljedne obrasce između zubnih lukova i među klasama, a ne na pojedinačne statistički značajne razlike.

Etička razmatranja

Ovo istraživanje provedeno je u skladu sa smjernicama navedenima u Helsinškoj deklaraciji (2013.). Odobrili su ga Etički odbor Stomatološkog fakulteta Sveučilišta u Zagrebu, Hrvatska (odobrenje br. 05-PA-30-XXIII-1/2021) i obrazovni uredi u svakom od sedam kosovskih gradova.

Za sudionike mlađe od 18 godina informirani pristanak potpisali su roditelji ili zakonski skrbnici, a sudionici u dobi od 18 godina i stariji to su učinili sami, uz usmeni pristanak svih adolescentnih sudionika. Svi su postupci provedeni u skladu s relevantnim institucionalnim i nacionalnim standardima istraživanja koja obuhvaćaju ljudske sudionike.

Rezultati

Obilježja uzorka

Distribucija istraživanog uzorka prema spolu i skupinama klasa okluzije prikazana je u tablici 1.

Table 1 Distribution of the study sample according to sex and occlusion classes groups (n = 400)
Tablica 1. Distribucija istraživanog uzorka prema spolu i skupinama klasa okluzije (n = 400)

Sex	Class I n (%)	Class II n (%)	Class III n (%)	Total n (%)
Male	102 (48.1%)	75 (45.2%)	7 (31.8%)	184 (46.0%)
Female	110 (51.9%)	91 (54.8%)	15 (68.2%)	216 (54.0%)
Total	212 (53.0%)	166 (41.5%)	22 (5.5%)	400 (100%)

Comparison of tooth size dimensions among occlusion classes

Mesiodistal widths (MD)

Mean mesiodistal (MD) values and standard deviations for each tooth and occlusion class are presented in Table 2. Occlusion classes were found to differ statistically significantly ($p < 0.05$), primarily in the maxillary anterior region and premolar region, and in selected mandibular canines, first premolars and first molars. In general, subjects in Class I tended to have slightly larger MD widths than Class II and Class III subjects, both in the anterior maxillary and premolar regions.

Buccolingual widths (BL)

The buccolingual (BL) measurements for all teeth and occlusion classes are shown in Table 3. The occlusion classes were not statistically significantly different for the majority of teeth. However, there were significant differences for mandibular incisors and first premolars.

Cervico-incisal height (CI)

Results for CI are summarized in Table 4. Significant differences in the CI were found among occlusion classes in both arches. Class I subjects tended to have increased CI in maxillary incisors and premolars, while the Class III subjects showed increased values in mandibular anterior and posterior teeth.

Usporedba dimenzija veličine zuba među klasama okluzije

Meziodistalne širine (MD)

Srednje vrijednosti meziodistalnih (MD) dimenzija i standardne devijacije za svaki zub i klasu okluzije nalaze se u tablici 2. Utvrđene su statistički značajne razlike među klasama okluzije ($p < 0,05$), uglavnom u području maksilarnih prednjih zuba i pretkutnjaka te na pojedinim mandibularnim očnjacima, prvim pretkutnjacima i prvim kutnjacima. Općenito, ispitanici klase I imali su nešto veće širine MD-a od ispitanika klasa II i III, i u prednjem području maksile i u području pretkutnjaka.

Bukolingvalne širine (BL)

Bukolingvalna (BL) mjerenja za sve zube i klase okluzije nalaze se u tablici 3. Za većinu zuba nisu pronađene statistički značajne razlike među klasama okluzije. No značajne razlike ustanovljene su za mandibularne sjekutiće i prve pretkutnjake.

Cervikoincizalna visina (CI)

Rezultati za CI sažeti su u tablici 4. Značajne razlike u CI-ju zabilježene su među klasama okluzije u oba zubna luka. Kod ispitanika klase I uočena je tendencija povećanih CI vrijednosti na maksilarnim sjekutićima i pretkutnjacima, a kod ispitanika klase III ustanovljene su povećane vrijednosti na mandibularnim prednjim i stražnjim zubima.

Table 2 MD crown dimensions across occlusion categories: mean values and standard deviations (SD)
Tablica 2. Dimenzije kruna u smjeru MD-a prema kategorijama okluzije: srednje vrijednosti i standardne devijacije (SD)

Tooth	Class I (Mean ± SD)	Class II (Mean ± SD)	Class III (Mean± SD)	p-value
11‡	9.15±0.55	9.04±0.57	8.95±0.74	0.087
12	7.00±0.62	6.88±0.55	6.71±0.70	**0.042***
13	8.27±0.52	8.18±0.52	7.93±0.81	**0.011***
14	7.26±0.43	7.14±0.49	7.04±0.53	**0.013***
15	6.95±0.47	6.90±0.53	6.83±0.49	0.492
16‡	10.16±0.69	10.17±0.54	10.04±0.72	0.795
17‡	9.56±0.71	9.54±0.70	9.42±1.29	0.794
21	9.15±0.55	9.05±0.59	9.06±0.79	0.248
22	6.97±0.55	6.82±0.56	6.71±0.77	**0.017***
23	8.23±0.54	8.15±0.54	7.73±0.72	**0.001****
24	7.28±0.46	7.11±0.52	7.05±0.57	**0.002****
25‡	6.92±0.50	6.81±0.54	6.72±0.53	0.064
26‡	10.24±0.70	10.15±0.53	9.96±0.61	0.063
27	9.64±0.67	9.56±0.54	9.48±0.71	0.333
31‡	5.86±0.44	5.86±0.42	5.79±0.48	0.680
32	6.38±0.42	6.36±0.40	6.20±0.53	0.169
33	7.28±0.54	7.22±0.50	6.88±0.61	**0.004****
34	7.36±0.50	7.26±0.49	7.10±0.64	**0.032***
35	7.30±0.53	7.27±0.49	7.06±0.49	0.110
36	11.26±0.82	11.05±0.70	10.96±0.84	**0.016***
37	10.08±0.74	10.05±0.63	10.08±0.83	0.889
41	5.81±0.40	5.77±0.38	5.93±0.71	0.200
42	6.25±0.40	6.26±0.41	6.12±0.45	0.297
43	7.18±0.54	7.12±0.50	6.96±0.64	0.147
44	7.36±0.48	7.26±0.53	7.14±0.60	0.060
45‡	7.25±0.51	7.26±0.58	7.07±0.47	0.340
46	11.24±0.80	11.10±0.71	10.97±0.90	0.106
47	10.31±0.72	10.17±0.69	10.27±0.62	0.161

* $p < 0.05$; ** $p < 0.01$; ANOVA test; ‡ Kruskal-Wallis test

Diagonal widths (MBDL and MLDB)

MBDL widths (Table 5) displayed a notable variation only in the upper right first molar ($p = 0.028$), where the mean value (11.56 mm) was the highest in Class I subjects. All other teeth demonstrated no significant interclass differences.

MLDB widths, shown in Table 6, were more variable. Maxillary premolars and multiple mandibular anterior teeth showed significant differences. Class I subjects had higher diagonal values of MLDB for maxillary premolars than others, and Class III subjects demonstrated higher diagonal values for mandibular anterior teeth.

Discussion

The present study expands traditional tooth-size analysis by including diagonal and vertical parameters as clinically relevant indicators of crown morphology in relation to occlusion classes. This study aimed to assess several odontometric tooth-size parameters in adolescents with different Angle occlusion classes in Kosovo. The results showed that mesiodistal (MD) and cervico-incisal (CI) crown dimensions demonstrated the greatest interclass variability. Class I subjects

Dijagonalne širine (MBDL i MLDB)

Za MBDL širine (tablica 5.) zabilježena je zamjetna varijacija samo na gornjemu desnom prvom kutnjaku (p = 0,028), pri čemu je srednja vrijednost (11,56 mm) bila najveća kod ispitanika klase I. Svi ostali zubi nisu pokazali značajne razlike među klasama.

MLDB širine, prikazane u tablici 6., imale su veće varijacije. Na maksilarnim pretkutnjacima i na više mandibularnih prednjih zuba uočene su značajne razlike. Kod ispitanika klase I zabilježene su veće dijagonalne vrijednosti MLDB-a na maksilarnim pretkutnjacima u odnosu prema ostalim klasama, a ispitanici klase III imali su veće dijagonalne vrijednosti za mandibularne prednje zube.

Rasprava

U ovom istraživanju proširuje se tradicionalna analiza veličine zuba uključivanjem dijagonalnih i vertikalnih parametara kao klinički relevantnih pokazatelja morfologije kruna u odnosu prema klasama okluzije. Svrha je bila procijeniti nekoliko odontometrijskih parametara veličine zuba adolescenata na Kosovu s različitim klasama okluzije prema Angleu. Rezultati su pokazali da su meziodistalne (MD) i cervikoincizalne (CI) dimenzije kruna imale najveću varijabilnost među klasa-

Table 3 BL crown dimensions across occlusion categories: mean values and standard deviations (SD)
Tablica 3. Dimenzije kruna u smjeru BL-a prema kategorijama okluzije: srednje vrijednosti i standardne devijacije (SD)

Tooth	Class I (Mean ± SD)	Class II (Mean ± SD)	Class III (Mean± SD)	p-value
11	7.38±0.51	7.31±0.61	7.26±0.69	0.331
12‡	6.56±0.54	6.51±0.62	6.59±0.79	0.639
13	8.20±0.68	8.04±0.80	8.02±0.79	0.082
14	9.39±0.58	9.32±0.61	9.29±0.55	0.404
15	9.55±0.66	9.48±0.73	9.46±0.60	0.602
16	10.93±0.70	10.98±0.69	10.99±0.64	0.791
17	10.59±0.84	10.59±0.80	10.72±0.76	0.773
21	7.39±0.53	7.31±0.63	7.26±0.62	0.300
22	6.57±0.55	6.51±0.56	6.60±0.79	0.484
23	8.26±0.63	8.11±0.72	8.28±0.82	0.073
24	9.37±0.57	9.27±0.62	9.25±0.50	0.192
25	9.52±0.62	9.46±0.65	9.30±0.55	0.252
26	10.96±0.68	10.99±0.64	11.02±0.52	0.907
27	10.59±0.75	10.55±0.73	10.74±0.73	0.510
31	6.24±0.48	6.18±0.46	6.53±0.87	**0.009****
32	6.54±0.46	6.48±0.43	6.74±0.68	**0.044***
33	7.52±0.66	7.45±0.67	7.68±0.89	0.237
34‡	8.07±0.61	7.96±0.52	7.86±0.78	0.248
35‡	8.68±0.59	8.59±0.66	8.48±0.64	0.462
36‡	10.58±0.58	10.54±0.88	10.36±0.79	0.724
37	10.09±0.63	9.99±0.72	10.01±0.80	0.339
41‡	6.23±0.46	6.19±0.50	6.54±0.94	0.281
42‡	6.46±0.47	6.43±0.45	6.75±0.95	0.234
43	7.46±0.66	7.41±0.66	7.61±1.00	0.420
44	8.14±0.60	8.01±0.56	7.92±0.72	**0.040***
45	8.74±0.62	8.69±0.54	8.51±0.71	0.207
46‡	10.61±0.58	10.61±0.57	10.45±0.76	0.996
47	10.04±0.65	9.97±0.72	10.02±0.78	0.570

* $p < 0.05$; ** $p < 0.01$; ANOVA test; ‡ Kruskal-Wallis test

had greater tooth sizes in the maxillary arch, while Class III subjects had larger cervico-incisal heights and diagonal measurements in the mandibular arch. Contrary, buccolingual (BL) crown dimensions exhibited least difference between the occlusion classes. These findings indicate that the crown dimensions of Kosovar adolescents display class-associated variations that may be important for the diagnosis and planning of orthodontic treatment.

Mesiodistal widths and interclass differences

Mesiodistal widths demonstrated some of the strongest interclass differences, with Class I subjects displaying greater values in the maxillary anterior and premolar regions than Class II and Class III subjects. These observations correlate well with traditional studies indicating mesiodistal crown dimensions to be primary factors affecting arch harmony and occlusal relationships (1-3). Similar interclass patterns with regard to different populations were found in the Turkish and Hispanic populations, with notable variations in the mesiodistal crown dimensions among malocclusion groups (5, 32).

Inter-population studies have shown that mesiodistal dimensions vary between ethnic groups, as evidenced by studies in Jordanian, Malay, Dominican, Chinese and multiethnic

ma. Ispitanici klase I imali su veće dimenzije zuba u maksilarnome luku, a kod ispitanika klase III zabilježena je veća cervikoincizalna visina i dijagonalne dimenzije u mandibularnom luku. Suprotno tomu, bukolingvalne (BL) dimenzije kruna najmanje su se razlikovale među klasama okluzije. Ti nalazi upućuju na to da dimenzije kruna zuba kosovskih adolescenata pokazuju varijacije povezane s klasom okluzije koje mogu biti važne za dijagnostiku i planiranje ortodontskog liječenja.

Meziodistalne širine i razlike među klasama

Meziodistalne širine pokazale su neke od najvećih razlika među klasama, pri čemu su ispitanici klase I imali veće vrijednosti u prednjem području maksilarnoga luka i u području pretkutnjaka nego ispitanici klasa II i III. Ta opažanja u skladu su s tradicionalnim istraživanjima prema kojima su meziodistalne dimenzije kruna primarni čimbenici koji utječu na sklad zubnoga luka i okluzijske odnose (1 – 3). Slični obrasci među klasama u različitim populacijama ustanovljeni su u turskoj i hispanskoj populaciji, uz zamjetne varijacije meziodistalnih dimenzija kruna među skupinama s malokluzijama (5, 32).

Istraživanja u populacijama pokazala su da se meziodistalne dimenzije razlikuju među etničkim skupinama, što potvrđuju istraživanja jordanske, malajske, dominikanske, kineske i multietničkih populacija (4, 6, 21, 23, 24, 26), či-

Table 4 Height of crowns across various occlusion categories
Tablica 4. Visina kruna prema različitim kategorijama okluzije

Tooth	Class I (Mean ± SD)	Class II (Mean ± SD)	Class III (Mean± SD)	p-value
11	8.95±0.96	8.85±0.95	9.06±1.11	0.447
12‡	7.35±0.77	7.28±0.85	7.24±0.95	0.448
13	8.33±0.88	8.18±0.96	8.56±0.97	0.089
14‡	6.97±0.73	6.82±0.78	7.19±1.04	**0.041***
15	5.94±0.70	5.83±0.80	6.12±0.85	0.145
16‡	5.02±0.69	5.02±0.73	5.33±0.75	0.094
17	4.47±0.79	4.40±0.83	4.80±1.03	0.100
21	9.04±0.94	8.91±1.01	9.22±1.02	0.234
22	7.45±0.83	7.25±0.91	7.80±1.31	**0.009****
23	8.45±0.91	8.24±1.01	8.73±1.40	**0.028***
24	7.07±0.69	6.81±0.74	7.22±0.79	**0.001****
25‡	6.07±0.74	5.84±0.79	6.02±0.96	**0.015***
26‡	4.96±0.75	4.96±0.83	5.15±0.86	0.664
27‡	4.46±0.80	4.34±0.90	4.54±1.02	0.183
31	7.75±0.82	7.53±0.85	7.97±0.75	**0.009****
32	7.77±0.76	7.58±0.88	8.14±0.93	**0.004****
33‡	8.76±1.00	8.64±1.07	9.12±1.55	0.385
34	7.69±0.69	7.47±0.80	7.84±1.13	**0.010***
35	6.76±0.65	6.58±0.66	6.89±0.86	**0.015***
36	6.08±0.57	5.86±0.61	6.06±0.72	**0.001****
37	4.98±0.71	4.76±0.68	4.93±0.81	**0.012***
41	7.73±0.80	7.56±0.77	8.09±0.85	**0.005****
42	7.75±0.77	7.57±0.82	8.09±1.06	**0.008****
43‡	8.68±1.12	8.59±1.00	8.79±1.56	0.867
44	7.69±0.68	7.54±0.68	7.61±0.76	0.134
45	6.78±0.68	6.58±0.65	6.77±0.92	**0.018***
46	6.08±0.59	5.94±0.59	5.99±0.80	0.095
47‡	4.90±0.77	4.67±0.79	4.97±0.91	**0.030***

* $p < 0.05$; ** $p < 0.01$; ANOVA test; ‡ Kruskal-Wallis test

nic populations (4,6,21,23,24,26), which further reinforce the need for reference standards specific to the population.

The consistency of these findings between different ethnic populations strongly supports the relevance of population-based reference values for improving diagnostic precision, with particular emphasis on space management and Bolton discrepancy measurements.

The increased mesiodistal dimensions of the maxillary incisors observed in Class I subjects may influence interarch tooth-size relationships and Bolton ratios. A relative excess of maxillary anterior tooth material may affect overjet, crowding patterns, and treatment planning decisions, including interproximal enamel reduction, restorative compensation, or extraction strategies. The observed mesiodistal differences may have implications for Bolton tooth-size ratios and interarch tooth-size discrepancies. In a previous study conducted in the same Kosovar population, a relatively high prevalence of anterior and overall tooth-size discrepancies was identified, and the anterior ratio differed significantly among occlusion classes (16). Since Bolton anterior ratios are derived from the proportional relationship between mandibular and maxillary mesiodistal tooth dimensions, the greater maxillary incisor width observed in Class I subjects may contribme se dodatno ističe da su potrebni referentni standardi specifični za pojedinu populaciju.

Dosljednost tih nalaza u različitim etničkim populacijama snažno podupire važnost referentnih vrijednosti utemeljenih na populaciji za poboljšanje dijagnostičke preciznosti, s posebnim naglaskom na upravljanje prostorom i mjerenje Boltonove diskrepancije.

Povećane meziodistalne dimenzije maksilarnih sjekutića uočene kod ispitanika klase I mogu utjecati na odnose veličine zuba između zubnih lukova i Boltonove omjere. Razmjerni višak dentalne supstancije u prednjem području maksilarne čeljusti može utjecati na horizontalni preklop ili pregriz (overjet), obrasce zbijenosti i odluke pri planiranju liječenja, uključujući interproksimalnu redukciju cakline, restaurativnu kompenzaciju ili ekstrakcijske strategije. Opažene meziodistalne razlike mogu imati implikacije za Boltonove omjere veličine zuba i diskrepancije u veličini zuba između zubnih lukova. U prethodnom istraživanju provedenom također na kosovskoj populaciji ustanovljena je razmjerno visoka prevalencija prednjih i ukupnih diskrepancija u veličini zuba, a prednji omjer značajno se razlikovao među klasama okluzije (16). Budući da se prednji Boltonovi omjeri dobivaju iz proporcionalnog odnosa između meziodistalnih dimenzija man-

Table 5 Diagonal crown width of MBDL across various occlusion categories
Tablica 5. Dijagonalna širina kruna u smjeru MBDL-a prema različitim kategorijama okluzije

Tooth	Class I (Mean ± SD)	Class II (Mean ± SD)	Class III (Mean± SD)	p-value
11	9.25±0.62	9.25±0.64	9.11±0.68	0.599
12	7.35±0.64	7.41±0.69	7.31±0.79	0.610
13 ‡	7.68±0.61	7.59±0.60	7.57±0.67	0.242
14	7.64±0.49	7.57±0.45	7.54±0.45	0.229
15 ‡	7.76±0.51	7.76±0.54	7.74±0.44	0.944
16	11.56±0.65	11.49±0.60	11.17±0.87	**0.028***
17 ‡	10.35±1.03	10.32±0.95	10.40±1.14	0.931
21	9.27±0.59	9.20±0.68	9.23±0.58	0.583
22 ‡	7.41±0.67	7.41±0.66	7.48±0.78	0.964
23	7.63±0.63	7.53±0.68	7.48±0.65	0.253
24	7.46±0.45	7.35±0.49	7.38±0.45	0.070
25	7.55±0.47	7.49±0.50	7.51±0.45	0.469
26 ‡	11.60±0.65	11.55±0.62	11.23±0.80	0.101
27 ‡	10.28±1.04	10.29±1.00	10.38±0.96	0.877
31	7.02±0.68	7.07±0.70	7.39±1.04	0.062
32	7.14±0.65	7.20±0.63	7.42±0.78	0.149
33	7.39±0.66	7.38±0.68	7.51±0.83	0.702
34	7.07±0.49	7.03±0.52	6.95±0.46	0.462
35 ‡	7.50±0.55	7.41±0.53	7.29±0.45	0.085
36 ‡	10.69±0.69	10.65±0.54	10.54±1.07	0.694
37 ‡	10.12±0.67	10.00±0.71	10.11±1.02	0.100
41 ‡	7.05±0.67	7.06±0.75	7.48±0.91	0.072
42	7.29±0.66	7.30±0.66	7.55±0.97	0.217
43	7.52±0.65	7.49±0.69	7.70±0.94	0.410
44 ‡	6.98±0.53	6.93±0.50	6.99±0.43	0.442
45	7.31±0.52	7.24±0.54	7.31±0.46	0.436
46	10.83±0.59	10.80±0.55	10.95±0.58	0.502
47	10.19±0.63	10.07±0.72	10.23±0.79	0.200

* $p < 0.05$; ** $p < 0.01$; ANOVA test; ‡ Kruskal-Wallis test

ute to the lower anterior Bolton ratios previously reported in this population. These findings suggest that even small variations in individual tooth dimensions may accumulate across the dental arch, influence interarch tooth-size relationships, and become clinically relevant during orthodontic diagnosis and treatment planning.

Buccolingual width stability across occlusion classes

The buccolingual dimensions showed minimal variation among the different types of occlusion classes. Only a few mandibular incisors and maxillary first premolars exhibited statistically significant differences, confirming the relative stability of buccolingual morphology.

Other studies that have also evaluated both the mesiodistal and buccolingual dimensions, found that the BL had less interclass variability than the MD (5, 23, 26). Although inter-populations variability in BL dimensions is observed (24), it does not appear to be as strongly related to malocclusion type as mesiodistal widths.

A possible functional explanation may relate to the lesser role of BL width in sagittal compensation and arch coordination, compared to MD and vertical crown components.

dibularnih i maksilarnih zuba, veće meziodistalne dimenzije maksilarnih sjekutića uočene kod ispitanika klase I mogu pridonijeti nižim prednjim Boltonovim omjerima prije utvrđenima u toj populaciji. Ti nalazi upućuju na to da se čak i male varijacije u dimenzijama pojedinačnih zuba mogu kumulirati duž zubnoga luka, utjecati na odnose veličine zuba između zubnih lukova i postati klinički relevantne tijekom ortodontske dijagnostike i planiranja liječenja.

Stabilnost bukolingvalne širine među klasama okluzije

Bukolingvalne dimenzije pokazale su minimalne varijacije među različitim klasama okluzije. Samo je nekoliko mandibularnih sjekutića i maksilarnih prvih pretkutnjaka pokazalo statistički značajne razlike, potvrđujući razmjernu stabilnost bukolingvalne morfologije.

U drugim istraživanjima, u kojima se također procjenjivala i meziodistalna i bukolingvalna dimenzija, istaknuto je da je BL imao manju varijabilnost među klasama od MD-a (5, 23, 26). Iako su uočene varijacije dimenzija BL-a među populacijama (24), čini se da one nisu tako snažno povezane s oblikom malokluzije kao meziodistalna širina.

Moguće funkcionalno objašnjenje može biti povezano s manjom ulogom širine BL-a u sagitalnoj kompenzaciji i koordinaciji zubnih lukova u usporedbi s MD-om i vertikalnim

Table 6 Diagonal crown width of MLDB across various occlusion categories
Tablica 6. Dijagonalna širina kruna u smjeru MLDB-a prema različitim kategorijama okluzije

Tooth	Class I (Mean ± SD)	Class II (Mean ± SD)	Class III (Mean± SD)	p-value
11	8.55±0.60	8.55±0.65	8.53±0.70	0.987
12	6.89±0.64	6.91±0.63	6.66±0.80	0.224
13	7.37±0.54	7.30±0.59	7.36±0.63	0.549
14	7.95±0.46	7.79±0.46	7.97±0.41	**0.001****
15	7.89±0.48	7.77±0.45	7.83±0.53	**0.047***
16 ‡	9.99±0.76	9.90±0.67	9.78±0.67	0.280
17	8.98±0.73	9.03±0.75	8.98±0.65	0.738
21 ‡	8.38±0.60	8.39±0.66	8.37±0.86	0.862
22 ‡	6.73±0.57	6.80±0.64	6.77±0.86	0.691
23	7.31±0.50	7.22±0.62	7.30±0.77	0.271
24	8.08±0.50	7.96±0.55	8.07±0.48	0.068
25	8.07±0.53	7.99±0.49	7.98±0.55	0.270
26	10.04±0.71	10.00±0.59	9.95±0.72	0.742
27	9.15±0.73	9.19±0.66	9.04±0.78	0.619
31	7.11±0.58	7.00±0.60	7.42±0.78	**0.006****
32	7.14±0.55	6.97±0.54	7.36±0.62	**0.001****
33	6.78±0.54	6.64±0.61	7.12±0.67	**0.001****
34 ‡	6.65±0.42	6.60±0.44	6.48±0.43	0.239
35	7.40±0.50	7.36±0.53	7.25±0.53	0.432
36 ‡	10.78±0.63	10.64±0.69	10.57±1.11	0.449
37	10.12±0.68	10.08±0.63	9.98±0.97	0.604
41 ‡	6.96±0.63	6.91±0.64	7.39±0.86	**0.010***
42 ‡	6.88±0.57	6.80±0.61	7.22±0.78	**0.004****
43 ‡	6.59±0.62	6.54±0.57	6.94±0.69	**0.041***
44	6.58±0.44	6.51±0.40	6.65±0.43	0.185
45	7.42±0.50	7.37±0.51	7.34±0.51	0.623
46	10.71±0.66	10.59±0.57	10.63±0.77	0.179
47	10.07±0.75	10.03±0.67	10.13±0.79	0.799

* $p < 0.05$; ** $p < 0.01$; ANOVA test; ‡ Kruskal-Wallis test

Because BL width influences arch form more than sagittal occlusion, its resistance to morphological adaptation may explain why BL values remain stable even in the presence of either severe Class II or Class III malocclusion.

Moreover, studies validating the precision of digital linear measurements corroborate the accuracy and reproducibility of buccolingual measurements on various model types (14, 15, 27, 28), which is consistent with the present findings.

Crown height variability

Cervico-incisal height (CI) exhibited notable interclass differences, particularly in the maxillary incisors and premolars (larger in Class I) and in the mandibular anterior and posterior teeth (larger in Class III).

In Class III subjects, the crown height and mandibular longitudinal growth may be inherited by same mechanism. Previous clinical and longitudinal studies have shown that crown height may vary with growth, including the study of Morrow et al. (29), and the orthodontic treatment may affect the length of the crown and the gingival thickness, which demonstrates a dynamic relationship between dental morphology and occlusal adaptation (30,31).

komponentama krune. Budući da širina BL-a više utječe na oblik zubnoga luka nego na sagitalnu okluziju, njezinom otpornšću na morfološku prilagodbu može se objasniti zašto vrijednosti BL-a ostaju stabilne čak i u slučajevima izraženih diskrepancija klasa II ili III.

Nadalje, u istraživanjima u kojima su autori validirali preciznost digitalnih linearnih mjerenja potvrđuje se točnost i reproducibilnost bukolingvalnih mjerenja na različitim vrstama modela (14, 15, 27, 28), što je u skladu s rezultatima ovog istraživanja.

Varijabilnost visine krune

Cervikoincizalna visina (CI) pokazala je zamjetne razlike među klasama, posebno kad je riječ o maksilarnim sjekutićima i pretkutnjacima (veće u klasi I) te mandibularnim prednjim i stražnjim zubima (veće su u klasi III).

Ispitanicima klase III visina krune i longitudinalni rast mandibule mogu biti naslijeđeni istim mehanizmom. Dosadašnja klinička i longitudinalna istraživanja pokazala su da se visina krune može mijenjati tijekom rasta, uključujući istraživanje Morrowa i suradnika (29), a ortodontsko liječenje može utjecati na duljinu krune i debljinu gingive, što pokazuje dinamičan odnos između dentalne morfologije i okluzijske prilagodbe (30, 31).

Therefore, measurement of the cervico-incisal height can provide clinically useful information for orthodontic diagnosis, particularly when evaluating vertical alignment, incisal overlap and smile aesthetics.

Diagonal measurements: three-dimensional indicators of morphology

Diagonal dimensions (MBDL and MLDB) were more informative about the three-dimensional morphology of the crowns. Subjects in Class III had significantly larger diagonal dimensions of the mandibular anterior teeth than those in Class I and Class II. Significant interclass differences were also observed in the maxillary premolars, with Class I and Class III subjects generally showing higher values than Class II subjects.

Since diagonal dimensions combine mesiodistal and buccolingual dimensions, these dimensions represent shape features that cannot be expressed with linear dimensions. Recent three-dimensional geometric and morphometric analyses have demonstrated that crown shape features also differ between malocclusion classes (8,11,32,33), and these studies indicate that morphological variation is not restricted to linear dimensions but may also include spatial modifications of crown shape. Diagonal values may offer helpful extra information for the analysis of the torque forces of brackets, arch forms, finishing techniques or complex Class III orthodontic treatments.

It is also important to consider that tooth morphology is influenced not only by the type of occlusion but also by jaw growth. The observed trends were consistent across multiple teeth in the same arch, and the biological relevance of the findings was supported despite multiple statistical comparisons.

Strengths and limitations

The strengths of this study include a large sample size (n = 400) representative of different geographic areas of Kosovo, and a comprehensive assessment of five odontometric parameters. The high intra-examiner reliability and low values of Dahlberg's error offer additional evidence of the validity of these results. Another advantage of this study is the young age of the sample, which minimized age-related changes in tooth morphology, such as occlusal and proximal wear.

This study's primary limitation was the small number of Class III subjects, which may have influenced the interclass statistical power. Additionally, interclass comparisons should be interpreted with caution because of the unequal distribution among the occlusion classes, in particular in the Class III group. This distribution reflects the natural prevalence of Class III occlusion in the studied population and may have reduced the statistical power to detect subtle differences between the occlusion groups. Additionally, the lack of digital scans and cephalometric skeletal measurements represents a limitation of this study, as it was based on dental plaster models. Therefore, future research incorporating 3D digital analysis and comprehensive skeletal assessment is recommended.

Another limitation relates to the cervico-incisal (CI) dimension, which represents clinical crown height and may be

Zato mjerenje cervikoincizalne visine može dati klinički korisne informacije kad je riječ o ortodontskoj dijagnostici, osobito pri razmatranju vertikalnoga poravnanja, preklopa sjekutića i estetike osmijeha.

Dijagonalna mjerenja: trodimenzionalni pokazatelji morfologije

Dijagonalne dimenzije (MBDL i MLDB) pružile su više informacija o trodimenzionalnoj morfologiji kruna. Ispitanici klase III imali su znatno veće dijagonalne dimenzije mandibularnih prednjih zuba nego oni klasa I i II. Velike razlike među klasama također su zabilježene za maksilarne pretkutnjake, pri čemu su ispitanici klasa I i III općenito imali veće vrijednosti nego oni iz klase II.

Budući da dijagonalne dimenzije objedinjuju meziodistalne i bukolingvalne dimenzije, one su značajke oblika koje se ne mogu izraziti linearnim dimenzijama. Novije trodimenzionalne geometrijske i morfometrijske analize pokazale su da se značajke oblika kruna također razlikuju među klasama malokluzije (8, 11, 32, 33), a ta istraživanja upućuju na to da morfološka varijacija nije ograničena na linearne dimenzije, nego može uključivati i prostorne promjene oblika krune. Dijagonalne vrijednosti mogu dati dodatne korisne informacije za analizu torzijskih sila bravica, oblika zubnih lukova, završnih faza ortodontskoga liječenja ili složenih ortodontskih liječenja malokluzije klase III.

Također je važno uzeti u obzir da na morfologiju zuba ne utječe samo vrsta okluzije nego i rast čeljusti. Uočeni obrasci bili su dosljedni kad je riječ o više zuba unutar istoga zubnoga luka, a biološku relevantnost nalaza podupiru rezultati unatoč višestrukim statističkim usporedbama.

Snage i ograničenja

Snaga ovog istraživanja uključuje veliki uzorak (n = 400) koji obuhvaća različita geografska područja Kosova te sveobuhvatnu procjenu pet odontometrijskih parametara. Visoka pouzdanost unutar ispitivača i male vrijednosti Dahlbergove pogreške daju dodatne dokaze o valjanosti tih rezultata. Dodatna prednost ovog istraživanja jest mladost ispitanika, čime je osigurano da se na minimum svedu promjene povezane s dobi koje utječu na morfologiju zuba, poput okluzijskoga i aproksimalnoga trošenja.

Glavno ograničenje ovog istraživanja bio je mali broj ispitanika klase III, što je moglo utjecati na statističku snagu za usporedbe među klasama. Uz to, usporedbe među klasama treba tumačiti s oprezom zbog nejednake raspodjele među klasama okluzije, posebno u skupini klase III. Ta raspodjela pokazuje prirodnu prevalenciju okluzije klase III u proučavanoj populaciji i mogla je smanjiti statističku snagu za otkrivanje suptilnih razlika između skupina okluzije. Nadalje, u istraživanju se nisu mogli rabiti digitalni skenovi, nego su se morali upotrebljavati gipsani modeli, a skeletna mjerenja dobivena kefalometrijskim radiogramima nisu bila uključena; zato se autorima budućih istraživanja preporučuje integracija trodimenzionalne digitalne analize i skeletne procjene.

influenced by the position of the gingival margin. Although subjects with visible gingival inflammation, gingival enlargement/hypertrophy, and gingival recession were excluded, no formal periodontal or gingival index was recorded. Therefore, minor variations in gingival margin position could not be completely controlled and may have influenced the CI measurements.

Another limitation of the present study is that the analyses were not stratified by sex and sex was not included as a covariate in the statistical models. Although the primary objective was to compare differences among Angle's occlusion classes, sexual dimorphism in tooth dimensions has been documented in the literature and may have influenced some of the observed associations. Future studies should investigate the combined effects of occlusion type and sex on tooth size.

Conclusions

Notable variations in crown dimensions were identified among Angle occlusion classes in Kosovar adolescents. Class I subjects exhibited relatively larger mesiodistal and cervico-incisal crown parameters in the maxillary arch, whereas Class III subjects showed increased cervico-incisal height and diagonal crown dimensions in the mandibular arch. Buccolingual crown widths differed minimally between the occlusion classes.

The results of this study indicate that crown dimensions and occlusion classes in Kosovar adolescents are associated. Therefore, considering population- and occlusion-specific crown dimensions is advised to provide a more accurate assessment of the space required for tooth movement, bracket positioning, and specific finishing procedures. Ultimately, this approach enhances diagnostic precision and treatment outcomes. Further studies utilizing skeletal parameters and three-dimensional digital analyses are needed to provide additional insights into the morphological characteristics of teeth and malocclusions.

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Drugo ograničenje odnosi se na cervikoincizalnu (CI) dimenziju koja pokazuje visinu kliničke krune i na koju može utjecati položaj gingivnoga ruba. Iako su ispitanici s vidljivom gingivnom upalom, povećanjem ili hipertrofijom gingive te gingivnom recesijom bili isključeni, nije zabilježen formalni parodontološki ili gingivni indeks. Zato se male varijacije u položaju gingivnoga ruba nisu mogle u cijelosti kontrolirati i mogle su utjecati na mjerenja CI-ja.

Dodatno ograničenje ovog istraživanja jest to što analize nisu bile stratificirane prema spolu te spol nije bio uključen kao suvarijanta u statističke modele. Iako je primarni cilj bio usporediti razlike među klasama okluzije prema Angleu, spolni dimorfizam u dimenzijama zuba dokumentiran je u literaturi i mogao je utjecati na neke od uočenih povezanosti. U budućim istraživanjima trebali bi se ispitati kombinirani učinci tipa okluzije i spola na veličinu zuba.

Zaključci

Kod kosovskih adolescenata utvrđene su zamjetne varijacije u dimenzijama kruna među klasama okluzije prema Angleu. Ispitanici klase I imali su razmjerno veće meziodistalne i cervikoincizalne dimenzije kruna u maksilarnome luku, a kod ispitanika klase III zabilježena je povećana cervikoincizalna visina i dijagonalne dimenzije kruna u mandibularnom luku. Bukolingvalne širine kruna minimalno su se razlikovale među klasama okluzije.

Rezultati ovog istraživanja upućuju na povezanost dimenzija kruna i klasa okluzije kod kosovskih adolescenata. Zato se preporučuje uzimanje u obzir dimenzija kruna specifičnih za populaciju i okluziju kako bi se omogućila preciznija procjena prostora potrebnog za pomicanje zuba pri odabiru položaja bravica i tijekom specifičnih završnih postupaka ortodontskog liječenja, što će rezultirati preciznijom ortodontskom dijagnostikom i uspješnijim ortodontskim liječenjem. Potrebna su daljnja istraživanja koja će uključivati skeletne parametre i trodimenzionalne digitalne analize da bi se dobile dodatne informacije o morfološkim značajkama zuba i malokluzije.

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Sažetak

Ciljevi: Procijeniti meziodistalne (MD), bukolingvalne (BL), cervikoincizalne (CI) i dijagonalne dimenzije [meziobukalno-distolingvalne (MBDL) i meziolingvalno-distobukalne (MLDB)] kruna trajnih zuba kosovskih adolescenata te ispitati njihov odnos s klasama okluzije prema Angleu. **Materijali i metode:** U ovo presječno istraživanje bilo je uključeno 400 kosovskih adolescenata u dobi od 13 do 19 godina. Uzorak se sastojao od 216 djevojaka (54 %) i 184 mladića (46 %) klasificiranih prema Angleovoj klasi I (n = 212; 53,0 %), klasi II (n = 166; 41,5 %) i klasi III (n = 22; 5,5 %). Dimenzije kruna trajnih zuba (isključujući treće kutnjake) mjerene su na dentalnim modelima digitalnim pomičnim mjerilom (preciznost 0,01 mm). Za statističku analizu primijenjeni su jednosmjerna ANOVA ili Kruskal-Wallisov test ($p < 0,05$). **Rezultati:** Utvrđene su značajne razlike među klasama u meziodistalnim (MD) i cervikoincizalnim (CI) dimenzijama maksilarnih sjekutića i pretkutnjaka ($p < 0,05$). Ispitanici klase I imali su najveće meziodistalne i cervikoincizalne dimenzije u maksilarnome luku u usporedbi s ispitanicima klase II i III. Suprotno tomu, kod ispitanika klase III zabilježene su najveće dijagonalne i cervikoincizalne dimenzije mandibularnih zuba. Bukolingvalne dimenzije pokazale su minimalne varijacije među klasama okluzije. **Zaključci:** Dimenzije kruna zuba kosovskih adolescenata značajno se razlikuju među klasama okluzije prema Angleu, pri čemu su uzorci specifični za pojedinu klasu najizraženiji u meziodistalnim, cervikoincizalnim i dijagonalnim mjerenjima. Ti rezultati upućuju na to da bi odontometrijske podatke specifične za okluziju i populaciju trebalo uključiti u ortodontsku dijagnostiku, analizu prostora i planiranje liječenja kako bi se poboljšala klinička preciznost u kosovskoj populaciji.

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