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Tooth size discrepancies in Kosovar adolescents with different malocclusion classes

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Abstract: The goal of this study was to evaluate tooth size discrepancies in Kosovar adolescents according to the Bolton's analysis, and to determine the differences between gender and malocclusion classes.

A sample of 400 Kosovar adolescents, aged 13–19 years with various malocclusion categories (class I, II, III) according to the Angle's classification, was randomly selected. The anterior tooth size ratio, overall tooth size ratio, posterior tooth size ratio, as well as distribution of tooth size discrepancies were assessed. The normality of distribution was assessed by the Kolmogorov-Smirnov test, the differences between genders by the Independent Sample T-test, the Mann-Whitney U-test, and differences among malocclusion groups by ANOVA, the Kruskal-Wallis, and the Dunn's post-hoc tests.

The tooth size ratios of men and women did not differ significantly. The results also demonstrated significant differences among the malocclusion classes only for the anterior tooth size ratio ($p<0.05$). The overall and posterior ratios did not differ significantly within malocclusion classes. The percentages of Kosovar subjects with a deviation of more than 2SD from the Bolton average for the anterior and overall ratios were 41.37 and 23.79, respectively.

The genders did not differ significantly regarding tooth size ratios. Among the malocclusion classes, the anterior ratio differed significantly. In Kosovar subjects, tooth size discrepancies tend to be higher compared to Bolton's averages.

Key words: dental cast analysis, tooth size discrepancies, Kosovar adolescents, Bolton analysis.

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Introduction

Tooth size discrepancies are commonly characterized as a significant redundancy of dental tissues in one dental arch compared to the opposite side (Fields 1981) but also as a disparity in the sizes of specific teeth (Proffit 2007). Although natural teeth are well matched in most people, Proffit (2007) estimates show that around 5% of the population has tooth size disparities.

To diagnose and treat orthodontic problems correctly, it is important to determine whether there are tooth size disparities between the upper and lower jaws. As a result, orthodontic treatment plans are altered by decreasing (interproximal reduction), enlarging (crowns or build-ups), or removing the teeth before completion (Cançado et al. 2017).

Orthodontists have used various methods to identify discrepancies between dental arches in patients. However, the Bolton analysis, based on the ratios of the mandibular and maxillary mesiodistal tooth diameters, is the most well-known and popular technique (Smith and Buschang 2000).

According to Bolton (1958), the mesiodistal tooth size of the maxilla and mandible should correspond to the best occlusion, overjet, and overbite at the end of orthodontic treatment. However, an intermaxillary tooth size disparity is among the numerous indicators that can impair the success of orthodontic treatments.

The interrelationship between tooth dimension ratios and malocclusion groups has been studied in the last century until today, and different results have been obtained. Currently, we have no information about tooth size discrepancies in our population. Consequently, the objective of this study was to identify tooth size discrepancies and to determine the significance of differences between genders and malocclusion classes among Kosovar adolescents.

Material and methods

Study population

The sample of this study included 400 teenagers (216 females and 184 males) aged 13 to 19 years (average age 15.17 years ±1.91 SD). Participants were residents of seven regional cities of the Republic of Kosovo and were randomly selected by the multistage cluster sampling in 14 different schools. The study's inclusion criteria were as follows: Kosovar nationality, aged 13–19 years; fully erupted permanent teeth, except third molars; no previous or ongoing orthodontic treatment; no tooth abrasion, attrition, or major restorations that might have affected a tooth's mesiodistal dimension; no fractured teeth, no abnormal tooth morphology; and good quality study casts. According to the Angle classification (1899), the 400 study participants were classified into three categories: Class I (N = 212), Class II (N = 166), and Class III (N = 22) (Figure 1). This study was approved by the Ethics Committee of the School of Dental Medicine at the University of Zagreb (05-PA-30-XXIII-1/2021).

Methods

An informative letter and a consent form were given to all study participants who fulfilled the criteria and were signed by them (if they were over 18 years old) or by their parent/witness (if they were under 18 years old).

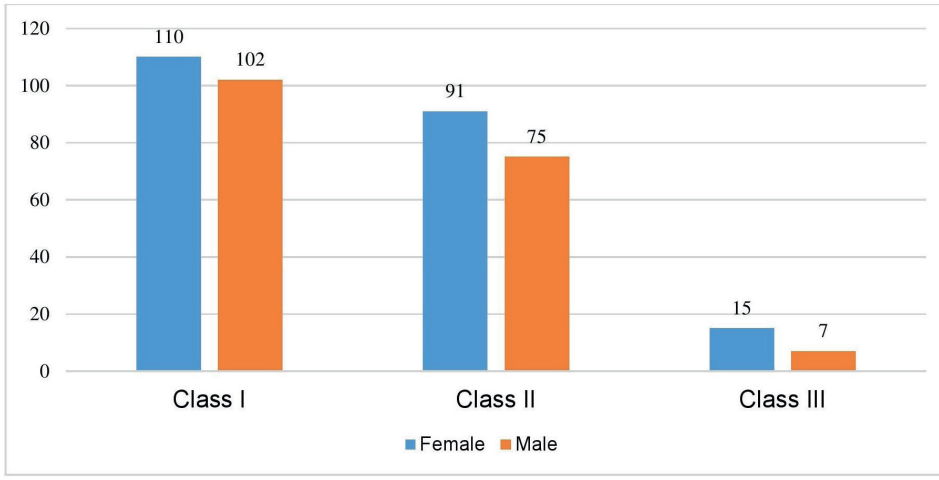

Fig. 1. The distribution of the sample according to gender and malocclusion groups (n=400)

Alginate was used to take impressions of the maxilla and mandible, and pre-orthodontic casts were made. Direct measurements of the MD width of teeth, from first molar to first molar, were taken of the pre-orthodontic casts with an electronic digital caliper (CD-6″ASX; Mitutoyo Corp., Kanagawa, Japan) to an accuracy of 0.01 mm (Figure 2).

Fig. 2. Measurement of the tooth size (MD width)

Bolton analysis

Tooth size ratios were determined following the Bolton's analysis (1958; 1962). The Bolton anterior ratio was calculated by dividing the sum of the widths of the lower and upper frontal teeth (from the canine to the canine) of both jaws. The result was then multiplied by 100.

$$anterior\ ratio = \frac{\sum (33 \leftrightarrow 43)}{\sum (13 \leftrightarrow 23)} \text{ x100}$$

The Bolton overall ratio was calculated by dividing the sum of the widths of the lower and upper teeth (from the first molar to the first molar) of both jaws. The result was then multiplied by 100.

$$overall\ ratio = \frac{\sum (36 \leftrightarrow 46)}{\sum (16 \leftrightarrow 26)} \text{ x100}$$

The Bolton posterior ratio was calculated by diving the sum of the widths of the lower and upper posterior teeth (from the first premolar to the first molar, on both sides of the jaws). The result was then multiplied by 100.

$$posterior\ ratio = \frac{\sum (36\leftrightarrow34, 44\leftrightarrow46)}{\sum (16\leftrightarrow14, 24\leftrightarrow26)} \text{x}100$$

All measurements were performed by the same researcher (B.Z.L.). To assess the examiner's measurement error, 30 randomly selected pairs of casts were premeasured 24 hours later by the same investigator. An Independent Sample T-test was used to determine the measurement error. The Dahlberg's formula was used to determine the deviation, ranging from -0.72 to 0.47 mm (Dahlberg 1940) (Table 1).

Each malocclusion type's percentage of tooth size disparity was calculated using the Bolton's standard. The entire number of study participants in the group was divided by the number of participants with tooth size ratios greater than 2SD. This value was multiplied by 100 (Strujić et al. 2009) (Figures 3 and 4).

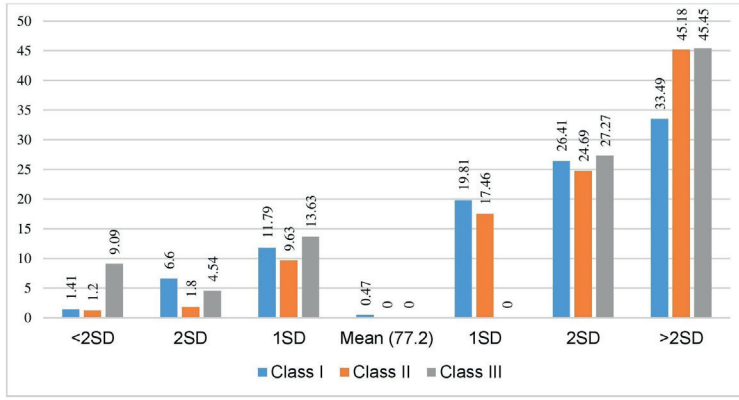

Fig. 3. The proportion of 400 participants with an anterior tooth size discrepancy compared to Bolton's norms

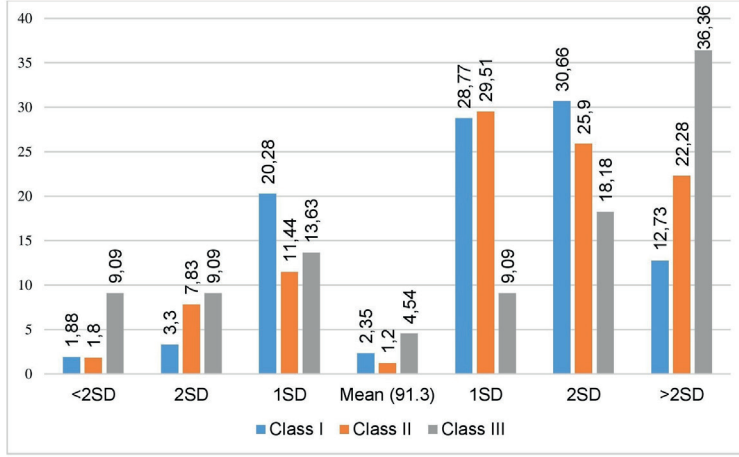

Fig. 4. The proportion of 400 participants with an overall tooth size discrepancy compared to Bolton's norms

Statistical analysis

Statistical analysis of the data was performed using SPPS version 25.0 (New York, USA).

Normal data distribution was analyzed using the Kolmogorov-Smirnov test. The data for the anterior tooth ratio were not distributed normally, while the data for overall and posterior ratios were distributed normally. Therefore, males and females were compared using the Independent Sample T-test and Mann-Whitney U-test. The variation among the three classes of malocclusions was analyzed using ANOVA, Kruskal-Wallis, and Dunn's post-hoc tests. A statistically significant p-value of 0.05 was used.

Results

The results of the T-test indicated that the differences between the two groups of measurements were not statistically significant (Table 1).

The descriptive data for the anterior, overall, and posterior ratios are shown in Table 2. Males and females did not show statistically significant differences ($p > 0.05$).

The Kruskal-Wallis test revealed that the anterior ratio differed significantly between malocclusion classes ($p<0.05$) (Table 3). Moreover, in subjects within class II, the greatest values for anterior ratio ($p<0.05$) were found. The ANOVA test revealed no significant differences in overall and posterior ratios between genders and malocclusion groups (Table 3).

On the other hand, the Dunn's post-hoc test showed significant differences in anterior ratio, more specifically between classes I and II ($p<0.05$) (Table 4).

Table 1. Descriptive statistics of tooth size ratios (n=30)

	Mean		SD		Mean difference	Lower	Upper	P-value	Dahlberg's error
	M1	M2	M1	M2					
Anterior ratio	79.93	79.46	2.81	2.82	0.47	-0.98	1.93	0.51	0.47
Overall ratio	92.46	92.48	2.32	2.25	-0.19	-1.37	0.99	0.74	-0.19
Posterior ratio	105.47	106.20	3.54	3.50	-0.72	-2.54	1.09	0.42	-0.72

Table 2. The differences in tooth size ratios between genders (n=400)

	Female and Male		Female		Male		F	Mean difference	P-values†,‡
	Mean	SD	Mean	SD	Mean	SD			
Anterior ratio ‡	79.81^	2.95	79.83^	3.06	79.80^	2.83	0.28	0.04	0.71
Overall ratio	92.89	2.62	92.84	2.73	92.97	2.50	0.39	-0.13	0.63
Posterior ratio	105.99	3.74	105.79	3.76	106.23	3.73	0.06	-0.44	0.24

Abbreviations: SD-Standard deviation; VAR-Variance; †Independent Sample T-test; ‡ Mann Whitney U-test; ^ Median

Table 3. The mean, standard deviation (SD), Kruskal-Wallis, and analysis of variance (ANOVA) tests for the anterior, posterior, and overall ratios and anterior and overall discrepancies in different malocclusion groups (n=400)

	Anterior ratio		Overall ratio		Posterior ratio	
	Mean	SD	Mean	SD	Mean	SD
Class I	79.37	2.69	92.69	2.27	106.02	3.22
Class II	80.31	2.87	93.12	2.77	105.96	4.22
Class III	80.41	4.90	93.21	4.20	105.97	4.78
P-value ‡	**0.012****		0.232		0.922	
FEMALE	Anterior ratio		Overall ratio		Posterior ratio	
	Mean	SD	Mean	SD	Mean	STD
Class I	79.30	2.76	92.45	2.23	105.59	3.11
Class II	80.30	2.71	93.21	2.81	106.01	4.24
Class III	80.92	5.69	93.45	4.72	105.89	5.12
P-value †	**0.024***		0.093		0.735	
MALE	Anterior ratio		Overall ratio		Posterior ratio	
	Mean	SD	Mean	SD	Mean	SD
Class I	79.44	2.62	92.95	2.29	106.48	3.28
Class II	80.33	3.08	93.01	2.73	105.91	4.23
Class III	79.31	2.50	92.69	3.05	106.12	4.35
P-value	0.108		0.947		0.607	

*, ** Statistically significant at 0.05; SD-Standard deviation; † ANOVA test; ‡ Kruskal-Wallis test

Table 4. Multiple comparisons between malocclusion classes in anterior ratio by post-hoc Dunn's test

Pairwise Comparisons of Classes					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	**Adj. Sig.**[a]
I-III	-30.069	25.896	-1.161	.246	.737
I-II	-34.791	11.982	-2.904	.004	**.011**
III-II	4.722	26.231	.180	.857	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Discussion

Tooth size discrepancies have been investigated all over the world to compare populations with specific features and identify trends in variability among dental arches. Their significance in orthodontic diagnosis is well documented in scientifically publications. The orthodontic society has acknowledged the importance of

the interrelationship between the maxillary and mandibular teeth to complete treatment (Araujo et al. 2003).

According to the current research, the average anterior tooth size ratio was 79.81 percent, which was higher compared to the Bolton's study (Table 2). Moreover, both genders and all malocclusion classes showed an average overall tooth size ratio of 92.89 percent, which was also higher compared to the value of 91.3 percent in the Bolton study (Table 2). The differences between populations and samples in the two studies can, to some extent, explain these findings. For example, Bolton used a small homogeneous group (55 Caucasian females) with excellent occlusion, whereas our study was conducted on schoolchildren and included 400 non-orthodontic subjects of both genders and different malocclusions.

Tooth size discrepancies and their prevalence

In 1962, Bolton suggested that a deviation from the average of over 1 SD indicates a requirement for diagnostic attention. His study found that 29% of his private practice patients had tooth-size disparities exceeding one standard deviation (Bolton 1962). In contrast, other researchers (Crosby and Alexander 1989; Freeman et al. 1996) interpreted the requirement as more than 2SD deviations from the Bolton standard. According to this, several studies have defined the prevalence of tooth size disparities and reported different results.

In the current study, the frequency of a significant disparity (more than 2 SD) in the anterior ratio was 41.37 percent (Figure 3), which is in accordance with previous findings in other populations (Akyalçin et al. 2006; Wedrychowska-Szulc et al. 2010; O'Mahony et al. 2011). Higher values indicate a trend for the mandibular tooth to be oversized in participants with class III. This suggests that the anterior maxillary teeth were smaller in subjects with class III compared to class II and class I. According to Akyalçin et al. (2006), there may have been considerable individual and cultural diversity in the growth pattern among the respondents.

In contrast, percentage values for anterior discrepancy ratio have been reported in Dominican American (Santoro et al. 2000), Southern Chinese (Ta et al. 2001), Brazilian (Araujo et al. 2003), Japanese (Endo et al. 2008), Jordanian (Al-Omari et al. 2008), Croatian (Strujić et al. 2009), Turkish (Uysal et al. 2005; Oktay and Ulukaya 2010), American (Johe et al. 2010), and Libyan (Bugaighis et al. 2015).

The incidence of a significant overall ratio discrepancy in the current study was 23.79 percent (Figure 4), which was similar to the results reported in a study carried out in a Turkish population (Oktay and Ulukaya 2010).

In contrast, Bolton (1958; 1962) and Proffit (2007) observed under 5 % of individuals with an overall ratio disparity of more than 2 SD. However, their studies comprised individuals with perfect occlusion, which could be assumed to be more typical of the normal community than of orthodontic patients. The prevalence obtained in the current study, however, was higher than reported in previous studies (Bolton 1958, 1962; Santoro et al. 2000; Bernabé et al. 2004; Proffit 2007; Al-Omari et al. 2008; Endo et al. 2008; Strujić et al. 2009; Wedrychowska-Szulc et al. 2010; Oktay and Ulukaya 2010; Bugaighis et al. 2015). However, Akyalçin et al. (2006) reported greater prevalence value compared to our study. Their study

sample was drawn from an orthodontic population, which could explain why they had the highest percentage of anterior tooth size discrepancies.

The higher frequency of statistically significant anterior tooth size discrepancies in the Kosovar population compared to the overall discrepancies suggests a significantly larger number of participants with proximal anterior tooth size disparities exhibiting more than 2 SD from the Bolton mean compared to study participants with overall disparities. The reason for this might be that the frontal teeth, particularly the upper and lower teeth, are significantly more prone to tooth size deviations. In other words, the anterior region exhibits the highest variability in mesiodistal tooth sizes (Uysal et al. 2005; Oktay and Ulukaya 2010). The latter might indicate that the prevalence of the Bolton discrepancy may differ between populations with different occlusal disorders. Therefore, clinicians ought to be aware of the frequent occurrence of TSDs while assessing and treating orthodontic patients. As a result, regardless of the malocclusion group, gender, or population, conducting Bolton's study routinely is strongly encouraged (Strujić et al. 2009; Johe et al. 2010).

Tooth size ratios and gender

Various studies have reported gender differences in tooth size proportions. In our study, no substantial difference was found between men and women according to the Bolton's tooth size ratios (Table 2). Previous studies (Crosby and Alexander 1989; Nie et al. 1999; Santoro et al. 2000; Ta et al. 2001; Araujo et al. 2003; Bernabé et al. 2004; Basaran et al. 2006; Al-Omari et al. 2008; Endo et al. 2008; O'Mahony et al. 2011; Bugaighis et al. 2015; Ismail and Abuaffan 2015; Mujagic et al. 2016; Hashim et al. 2017; Machado et al. 2018) have also reported no gender differences in tooth size proportions. On the other hand, some previous studies (Moorrees et al. 1957; Lavelle 1972; Richardson and Malhotra 1975; Smith et al. 2000; Uysal et al. 2005) compared the tooth size ratios between men and women and found considerable disparities. For example, Moorrees et al. (1957) found gender differences only in the overall ratio. Lavelle (1972) compared the overall and anterior tooth ratios between males and females and concluded that males had the highest ratios. Smith et al. (2000) discovered that men had considerably higher overall and posterior ratios compared to women. Oktay and Ulukaya (2009) noted sexual dimorphism only for the posterior ratio. In contrast, Richardson and Malhotra (1975) reported no changes in tooth-size proportions between the anterior and posterior arches. Mollabashi et al. (2019) discovered a substantial gender disparity in the posterior and overall ratios, whereas Strujić et al. (2009) found gender differences only in the anterior ratio. Therefore, the above studies suggest that a variation related to tooth size ratios depending on gender must be calculated separately for each population. Overall, most studies reveal no significant difference between tooth size ratios and gender.

Tooth size ratios in different malocclusion classes

The fact that tooth size variation is not systemic proves that populations differ in terms of tooth size ratios between arches. The variation in maxillary tooth size by population and gender is not correlated with differences in mandibular tooth size, so that different tooth size ratios are observed between arches (Smith et al. 2000).

The current study showed that only the anterior ratio differed significantly among the malocclusion classes ($p<0.05$), but neither the overall ratio nor the posterior ratio differed significantly (Table 3, 4). On the other hand, Strujić et al. (2009) and Oktay and Ulukaya (2009) reported contrasting findings. There were no significant differences in the anterior tooth ratios among the malocclusion classes. They did, however, discover substantial changes in the overall and posterior ratios. Moreover, several previous studies (Ta et al. 2001; Uysal et al. 2005; Basaran et al. 2006; Al-Khateeb et al. 2006; Lopatiene and Dumbravaite, 2009; O'Mahony et al. 2011) among different populations reported no significant variation between the malocclusion classes in anterior and overall ratios. Other researchers (Sperry et al. 1977; Nie et al. 1999), on the other hand, reported that the overall tooth size ratios were higher in class III than in classes I and II. According to Araujo and Souki (2003), class III subjects had a substantially larger anterior tooth size discrepancy than class I and II subjects. The tendency toward greater tooth size proportions in class III was also observed in the Chinese population by Ta et al. (2001).

Comparison between gender and classes

The present study found no substantial disparities between the genders and classes in the anterior, overall, and posterior ratios (a p-value of 0.05) (Table 3). The results of our study are consistent with other studies (Smith and Buschang 2000; Akyalçin et al. 2006; Endo et al. 2008; Alam et al. 2013; Cançado et al. 2015), which showed no significant gender differences in Bolton ratios in the anterior and overall regions by malocclusion category. On the other hand, according to Lavelle (1972), tooth size varies across different occlusal categories and populations. The results of our study were not consistent with those reported by Fattahi et al. (2006), who discovered gender variation in the anterior ratios of malocclusion classes but not in the overall ratios.

Further, O'Mahony et al. (2011) reported that males in classes II division 2 and III had the largest average anterior tooth size ratios, as opposed to classes I and II division 1. In contrast, Uysal and Sari (2005) noted no significant differences between the genders within the normal occlusion group, except for the overall ratio in the Turkish population.

Strengths and limitations

Although our study is not without its limitations, we recognize that it has some strengths as well. One of the strengths of our study is that the schoolchildren participating in the study were sampled from different cities, indicating a representative sample. In addition, they all met the study requirements. On the other hand, one of the limitations can be that our sample consisted of a general population with different malocclusions. Another limitation is that the measurements were made using a 2D method rather than a 3D method. Therefore, future work should focus on orthodontic Kosovar subjects and use a 3D method for the measurements.

These results suggest that the national criteria for clinical status are required. As the Bolton statistics are not representative of the non-orthodontic Kosovar population, these data should not be used in regular orthodontic diagnosis and treatment for Kosovar orthodontic patients. As a result, clinicians

need to be aware of the occurrence of TSDs and therefore, Bolton's analysis is necessary.

Conclusions

The following conclusions can be derived from our study's findings:

1. The averages and standard deviations of the anterior and the overall ratios were higher in the current study than in Bolton's research.
2. The tooth size ratios of men and women did not differ significantly.
3. Class II malocclusion showed the anterior ratio difference between classes.
4. Among Kosovar adolescents with more than two SD from Bolton's averages, the anterior tooth size ratio was 41.37 %, and the overall tooth size ratio was 23.79%.

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Conflict of interests

None.

Financial support

None.

Authors' contributions

BZL: Conceptualization, Methodology, Validation, Writing-Original draft preparation, reviewing, and editing. BK: Data curation, Visualization. SM: Writing-Reviewing and Editing, Supervision, Project administration.

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