Original Article

Intermaxillary Tooth Size Discrepancy and Malocclusion: Is There a Relation?

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Abstract: The aims of this study were to identify the possible sex differences in tooth size ratios between males and females, to determine whether there is a difference in the incidence of tooth size discrepancies for both the anterior and overall ratios when comparing with Angle Class I; Class II, division 1; Class II, division 2; and Class III malocclusion groups, to compare the tooth size ratios of different malocclusion groups with the anterior and overall tooth size ratios of 150 untreated normal occlusion subjects. In addition, the aim was to determine the percentage of tooth size discrepancies outside 2 SD from Bolton means for tooth ratios present in each malocclusion group and in the overall sample of this study. This study consisted of 150 subjects who served as the normal occlusion group and 560 patients who showed four different malocclusion characteristics (Angle Class I; Class II, division 1; Class II, division 2; and Class III). Tooth size measurements were performed on the models of normal occlusion and pretreatment models. For statistical evaluation, Student's *t*-test, analysis of variance and Tukey Honestly Significant Difference tests were performed. A significant sex difference was found only in the overall ratio for normal occlusion subjects ($P < .001$). All malocclusion groups showed statistically significant higher overall ratios than the normal occlusion group ($P < .001$). There were no statistically significant differences among malocclusion groups; however, there were a large number of patients within each group who had discrepancies greater than 2 SD from the mean. Further investigations are needed to explain the probable racial differences and relationships between malocclusion and tooth size measurements. (*Angle Orthod* 2005;75:208–213.)

Key Words: Bolton; Tooth size discrepancy; Malocclusion

INTRODUCTION

The concept of ideal intercuspation assumes a strict relationship between tooth size and the size of maxillary and mandibular arches.[1] Specific dimensional relationships must exist between the maxillary and mandibular teeth to ensure proper interdigitation, overbite, and overjet. Because patients with interarch tooth size discrepancies require either removal (eg, interdental stripping) or addition (eg, composite buildups or porcelain veneers) of tooth structure to open or close spaces in the opposite arch, it is important to determine the amount and location of a tooth size discrepancy before starting treatment.[2]

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Black[3] was one of the first investigators to measure tooth sizes, and his tables of mean tooth sizes are still used today. The tooth size measurements of Wheeler[4] also are frequently used. Bolton,[5] in 1958, analyzed the relationship between the mesiodistal tooth width of maxillary and mandibular teeth by studying 55 Caucasian subjects with excellent occlusion. Using the mesiodistal width of 12 teeth, he obtained an overall ratio of 91.3 ± 1.91%; using the six anterior teeth, he obtained an anterior ratio of 77.2 ± 1.65%.

The dental literature is replete with studies comparing tooth size discrepancy and malocclusion in different ethnic groups. However, only a few of them were interested in sex and Angle classification specificity, and additional data are necessary to understand this relationship.

Crosby and Alexander[6] studied 109 Caucasian orthodontic patients with varying malocclusions (Class I; Class II, division 1; Class II, division 2; Class II surgery) and found no statistically significant difference in the incidence of tooth size discrepancies among these groups. Similarly, Nie and Lin[7] compared 60 subjects who served as the normal occlusion group with 300 patients divided into five malocclusion groups and found significant differences for all the ratios between Class I, Class II, and Class III groups.

The intermaxillary tooth size ratios of this study showed that Class III subjects had higher tooth size ratios than Class I and Class II subjects. Araujo and Souki[8] investigated the prevalence of anterior tooth size discrepancy among the three malocclusion groups in the Brazilian population. They concluded that individuals with Angle Class I and Class III malocclusions show significantly greater prevalence of tooth size discrepancies than do individuals with Class II malocclusions, and mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and II subjects. Sperry et al[9] analyzed the Bolton ratios for groups of Class I, II, and III cases. The skeletal patterns were not mentioned, and the male and female subjects were not differentiated. This study did show a mandibular tooth size excess for the Class III patients.

Arya et al[10] showed that there were differences in tooth size between sexes, as reported by a number of authors. Lavelle[11] showed that there was sexual dimorphism in tooth dimensions and in the ratio of upper to lower arch tooth size. However, Nie and Lin[7] indicated no significant sexual dimorphism for anterior and posterior tooth size ratios in different malocclusion groups.

The aims of this study were: (1) to identify the possible sex differences in tooth size ratios between male and female subjects, (2) to determine whether there is a difference in the incidence of tooth size discrepancies for both the anterior and the overall ratios when comparing Class I; Class II, division 1; Class II, division 2; and Class III malocclusion groups, (3) to compare the tooth size ratios of different malocclusion groups with the anterior and overall tooth size ratios of 150 untreated normal occlusion subjects, and (4) to determine the percentage of tooth size discrepancies outside 2 SD from Bolton means for tooth ratios present in each malocclusion group and in the overall sample of this study.

MATERIALS AND METHODS

The samples for the study consisted of 150 subjects with normal occlusion and 560 patients with varying malocclusions. Data on normal occlusion subjects were from Uysal's PhD thesis.[12] Patients were selected randomly from the clinical practice of the Department of Orthodontics, Faculty of Dentistry, Selcuk University.

In the normal occlusion group, orthodontic dental casts were made for 150 Turkish subjects (72 men, mean age 22.09 ± 3.11 years and 78 women, mean age, 21.11 ± 2.08 years) with ideal occlusion and well-balanced faces. The following selection criteria were used in selecting the normal occlusion group:

- Turkish with Turkish parents;
- 20 to 35 years of age;
- Class I occlusion with minor or no crowding;
- Well-aligned upper and lower dental arches;
- Good quality study models.

In the malocclusion groups, all patients were between 13 and 18 years of age. The following selection criteria were used in selecting malocclusion groups[1]:

- Good quality of pretreatment models;
- Complete permanent dentition from 6 to 6;
- Absence of mesiodistal and occlusal abrasions or carries or Class II fillings;
- Absence of dental prosthesis;
- Absence of partially erupted teeth;
- Absence of tooth anomalies such as form, structure, and development, whereas the less objectionable anomalies such as macrodontia and microdontia were included. Cases of fusion of teeth and gemination were excluded because it was not possible to analyze the specific size of teeth, whereas the presence of conical teeth was not considered an exclusion criterion because it represented the morphological identity of these teeth.

The following rejection criteria were used in selecting groups:

- Gross restorations, buildups, crowns, onlays, Class II amalgams, or composite restorations that affect the tooth's mesiodistal diameter;
- Congenital defects or deformed teeth;
- Obvious interproximal or occlusal wear of teeth.

Sagittal relationships were classified according to Angle criteria, whereas the skeletal diagnosis was made on the basis of Steiner ANB angle:

- Class I, $0° < ANB < 5°$;
- Class II, $ANB > 5°$;
- Class III, $ANB < 0°$.

Malocclusion groups comprised 560 individuals with the following distribution: Class I (6 males and 150 females); Class II, division 1 (75 males and 82 females); Class II, division 2 (11 males and 23 females); and Class III (58 males and 55 females).

A digital caliper was used to measure the casts to the nearest 0.01 mm. The mesiodistal crown diameters of all teeth were measured according to the method described by Moorrees et al.[13] The width of each tooth was measured from its mesial contact point to its distal contact point at its greatest interproximal distance. Bolton anterior (canine to the canine) and overall (first molar to first molar) ratios were calculated with the following formulas.

$$\frac{\text{sum mandibular ''12''}}{\text{sum maxillary ''12''}} \times 100 = \text{overall ratio (\%)}$$

$$\frac{\text{sum mandibular ''6''}}{\text{sum maxillary ''6''}} \times 100 = \text{anterior ratio (\%)}$$

Bolton normal range values were used in the classification of normal and malocclusion groups. According to the Bolton analysis, a significant discrepancy was defined as

TABLE 1. Tooth Size Ratios and Gender Comparisons of Normal Occlusion and Malocclusion Groups.[a]

	Females				Males				
	X	SD	SE	Range	X	SD	SE	Range	*P* value
Normal occlusion									
AR	78.33	2.42	0.27	73.64–84.23	78.18	2.82	0.33	72.47–88.43	NS
OR	91.73	2.26	0.25	84.91–98.68	89.83	2.33	0.27	84.91–95.75	***
Class I malocclusion									
AR	78.44	3.18	0.26	68.36–78.56	78.74	3.31	0.32	68.36–90.61	NS
OR	91.57	2.98	0.24	70.49–102.92	91.65	3.51	0.34	70.49–99.75	NS
Class II, division 1 malocclusion									
AR	78.35	3.59	0.40	70.21–88.85	78.68	3.06	0.35	68.94–84.96	NS
OR	91.07	3.96	0.44	73.34–98.63	91.19	2.53	0.29	83.94–98.45	NS
Class II, division 2 malocclusion									
AR	78.70	4.64	0.97	71.21–95.90	79.63	3.35	1.01	75.00–86.25	NS
OR	89.81	4.65	0.97	88.06–100.66	90.81	2.27	0.69	85.96–94.02	NS
Class III malocclusion									
AR	78.03	3.06	0.30	70.23–84.26	79.59	3.67	0.35	72.34–88.33	NS
OR	91.01	3.56	0.35	76.60–95.66	92.34	3.67	0.34	78.00–101.15	NS

[a] AR indicates anterior ratio; OR, overall ratio; X, mean; SD, standard deviation; SE, standard error; NS, not significant.
*** $P < .001$.

one whose value was outside of 2 SD from Bolton mean[14] and approximately 95% of Bolton cases were within this range. Therefore, for the overall ''12'' ratio, a significant discrepancy is defined as a ratio below 87.5 or above 95.1, with ratios in-between falling within 2 SD of Bolton mean. Similarly, any ratio below 73.9 or above 80.5 is considered to be a significant discrepancy for the anterior ''6'' ratio.

All statistical analyses were performed using the SPSS software package (Statistical Package for Social Sciences, Windows 98, version 10.0, SPSS Inc., Chicago, Ill). For each variable, mean (X), standard deviation (SD), standard error (SE), minimum (min), and maximum (max) values were calculated for each measurement and separately for males and females. To determine whether there are sex differences in the incidence of intermaxillary tooth size discrepancies, a Student's *t*-test was performed. To statistically compare the prevalence of anterior and overall tooth size discrepancies among the malocclusion groups, analysis of variance (ANOVA) and Tukey Honestly Significant Difference (HSD) test were performed.

RESULTS

To determine the errors associated with measurement, 25 dental casts were selected randomly. Their measurements were repeated eight weeks after the first measurement. A paired *t*-test was applied to the first and second measurements. It was found that the difference between the first and second measurements of the 25 dental casts to determine the errors associated with measurements was insignificant.

Table 1 summarizes the means, standard deviations, standard errors, ranges, and statistical comparisons of the tooth size ratios observed in each group. It shows that there is no significant sexual dimorphism for anterior ratios of all groups. Statistically significant sex differences were found only in the overall ratio for normal occlusion group ($P < .001$). Comparison between the male and female subjects indicated larger measurements for males in all investigated measurements except the anterior ratio for normal occlusion and the overall ratio for Class I malocclusion.

Because there was no significant sexual dimorphism between subcategories of malocclusion, the sexes were combined for each group. ANOVA was used in comparisons of different malocclusion groups and demonstrated that there was no statistically significant difference among the four malocclusion groups for anterior and overall ratios (Table 2).

TABLE 2. ANOVA Comparisons of Anterior and Overall Tooth Size Ratios Among Different Malocclusion Groups.[a]

	Total Group				
	X	SD	SE	Range	*P* value
Class I malocclusion					
AR	78.56	3.23	0.20	68.36–93.65	NS
OR	91.90	3.21	0.20	70.49–102.92	NS
Class II, division 1 malocclusion					
AR	78.50	3.34	0.27	68.94–88.85	NS
OR	91.12	3.34	0.27	73.34–98.63	NS
Class II, division 2 malocclusion					
AR	79.00	4.23	0.73	71.21–95.90	NS
OR	91.94	3.14	0.54	85.96–100.66	NS
Class III malocclusion					
AR	78.83	3.46	0.33	70.23–88.33	NS
OR	91.69	3.66	0.34	76.60–101.15	NS

[a] AR indicates anterior ratio; OR, overall ratio; X, mean; SD, standard deviation; SE, standard error; NS, not significant.

TABLE 3. Turkey HSD Comparisons of Anterior and Overall Tooth Size Ratios Among Normal Occlusion and Different Malocclusion Groups.[a]

	Group	X	SD	1	2	3	4	5	Test[b]	Order
Anterior Ratio										
Normal occlusion	1	78.26	2.61						A	
Class I malocclusion	2	78.56	3.23						A	
Class II, division 1 malocclusion	3	78.50	3.34						A	group 4 > 5 > 2 > 3 > 1
Class II, division 2 malocclusion	4	79.00	4.23						A	
Class III malocclusion	5	78.83	3.46						A	
Overall Ratio										
Normal occlusion	1	89.88	2.29		***	**	**	***	B	
Class I malocclusion	2	91.90	3.21	***					C	
Class II, division 1 malocclusion	3	91.12	3.34	**					C	group 4 > 2 > 5 > 3 > 1
Class II, division 2 malocclusion	4	91.94	3.14	**					C	
Class III malocclusion	5	91.69	3.66	***					C	

[a] X indicates mean; SD, standard deviation.
[b] Groups with different letters are significantly different in each group.
** $P < .01$, *** $P < .001$.

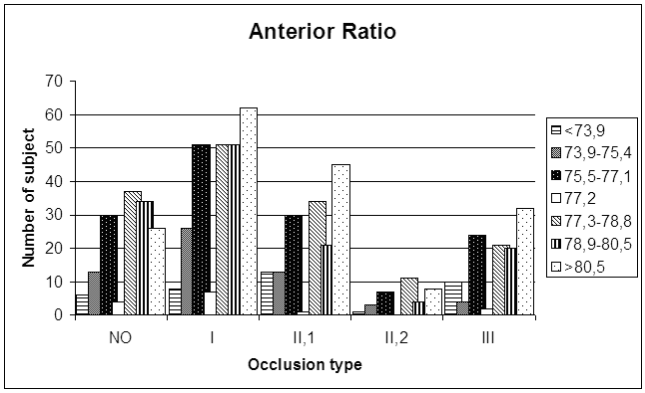

FIGURE 1. Distribution of Turkish population's anterior ratio values according to the Bolton mean and 2 SD.

ANOVA and Tukey HSD analysis were used in comparisons of tooth size ratios of different malocclusion groups with the anterior and overall tooth size ratios of 150 untreated normal occlusion subjects. Table 3 represents the statistical comparison results of five groups. According to the ANOVA, significant differences were found only in overall ratio ($P < .001$). The multicomparison was performed among normal occlusion and malocclusion groups for the overall ratio. The Tukey HSD analysis indicated that all malocclusion groups show statistically significant higher overall ratios than normal occlusion group. These differences were significant for Class I and Class III malocclusion groups at the $P < .001$ level and significant for Class II, division 1 and Class II, division 2 malocclusion groups at the $P < .01$ level.

TABLE 4. The Percentage Distribution of Anterior and Overall Tooth Size Descrepancies Outside 2 SD from Bolton's Means.

	Anterior Ratio						
	Outside SD (%)	SD 2 (%)	SD 1 (%)	Mean (%)	SD 1(%)	SD 2 (%)	Outside SD (%)
	<73.9	73.9–75.4	75.5–77.1	77.2	77.3–78.8	78.9–80.5	>80.5
Normal occlusion	4.00	8.67	20.00	2.67	24.67	22.67	17.33
Class I malocclusion	3.13	10.16	19.92	2.73	19.92	19.92	24.22
Class II, division 1 malocclusion	8.28	8.28	19.11	0.64	21.66	13.38	28.66
Class II, division 2 malocclusion	2.94	8.82	20.59	0.00	32.35	11.76	23.54
Class III malocclusion	8.85	3.54	21.24	1.77	18.58	17.70	28.32
	Overall Ratio						
	Outside SD (%)	SD 2 (%)	SD 1 (%)	Mean (%)	SD 1(%)	SD 2 (%)	Outside SD (%)
	<87.5	87.5–89.3	89.4–91.2	91.3	91.4–93.2	93.3–95.1	>95.1
Normal occlusion	16.00	28.00	28.67	2.00	20.67	2.66	2.00
Class I malocclusion	5.08	14.45	23.83	2.34	28.13	17.97	8.20
Class II, division 1 malocclusion	8.92	15.92	26.11	1.27	21.02	19.76	7.00
Class II, division 2 malocclusion	2.94	17.65	23.53	0.00	29.41	17.65	8.82
Class III malocclusion	5.31	12.39	19.47	1.77	29.20	20.35	11.51

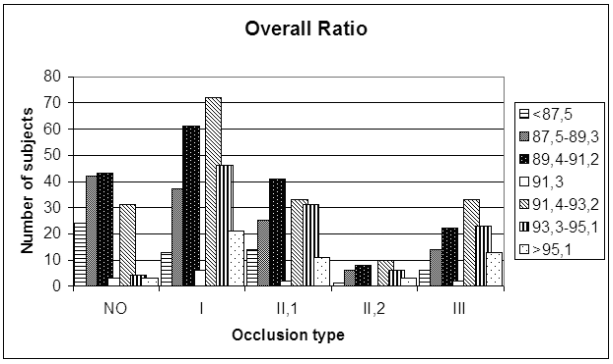

FIGURE 2. Distribution of Turkish population's overall ratio values according to the Bolton mean and 2 SD.

The frequency of tooth size discrepancy outside 2 SD from the Bolton mean for overall and anterior ratios was calculated for all malocclusion groups. Table 4 and Figures 1 and 2 summarize the categorization of values according to Bolton mean. It was determined that most of the patients had a higher anterior ratio outside the Bolton 2 SD, especially in Class I; Class II, division 1; and Class III malocclusion groups. However, for overall ratio, most of the values were inside 2 SD of Bolton mean.

DISCUSSION

The importance of tooth size discrepancies in orthodontic diagnosis has been widely reported in the literature and accepted by the orthodontic community because the relationship between the upper and lower anterior and posterior dentitions is related to orthodontic finishing excellence.[8] In the present study, prevalence of intermaxillary tooth size discrepancy and comparisons in different malocclusion groups in Turkish population were studied. Subjects in younger age groups were chosen to minimize the alteration of the mesiodistal tooth dimensions because of factors such as attrition or restoration or carries.

Nie and Lin[7] stated that some skeletal Class II malocclusions can be converted to dental Class I malocclusions by forward movement of permanent first molar due to the premature loss of the deciduous second molar, so that the Class I group may contain skeletal Class I and Class II patients. Therefore, in the current study all malocclusion groups were divided according to skeletal categories. Moreover, the criteria of occlusal categories of division 1 and division 2 groups coincided with the skeletal categories during subcategorization of the Class II malocclusion patients.

Importantly, studies[15,16] with similar ratios for males and females suggest that sex differences in the overall ratio may be population specific. Nie and Lin[7] found no statistically significant sex differences in a Chinese population. Smith et al[2] found larger overall ratios in males in black, Hispanic, and white populations. Lavelle[11] also reported relatively larger overall ratios in males compared with females in white, black, and Mongoloid populations. The tooth size data reported by Moorrees et al[13,17] also imply sex differences in the overall ratio, which agrees with our findings in the normal occlusion group. The statistically significant difference was because of both the anterior and posterior arch segment relationships, even though only the posterior ratio showed a significant difference in the present study. Anterior ratio measurements of both males and females follow a similar pattern distribution. Significant overall differences in normal occlusion groups could be explained by the relatively larger mandibular arch segments of men.

Sperry et al[9] showed that the Class III group with mandibular prognathism had more patients with mandibular tooth size excess for the overall ratio than the Class I and Class II groups. Similarly, Lavelle[11] and Nie and Lin[7] showed that Class III cases are characterized by smaller maxillary tooth dimensions and bigger lower teeth. In the Chinese population,[7] there is no incidence of tooth size discrepancy in Class I cases, including those with bimaxillary protrusion. But Class II and III patients show a tendency for this harmony. These authors reached these conclusions through comparisons of mean values in the three malocclusion groups.

Crosby and Alexander[6] also compared the tooth size ratios among different malocclusion groups, as in the current study. They found that there was no significant difference among Class I; Class II, division 1; Class II, division 2; and Class II surgery groups. In the present study, four malocclusion groups were compared, and no statistically significant difference was found among them. Our findings were similar with Crosby and Alexander[6] for Class I; Class II, division 1; and Class II, division 2 malocclusions. But for patients with Class III malocclusion, the present findings were not in accordance with Nie and Lin,[7] Sperry et al,[9] and Lavelle.[11]

Most investigators have concluded that there are significant differences between the separate ethnic and racial groups; as a result, a large number of standards have been developed for different ethnic groups. Most of the studies indicated that normal measurements for one group should not be considered normal for every race or ethnic group. Different racial groups must be treated according to their own characteristics. Xia and Wu[18] found no significant difference for tooth size ratios between the malocclusion group and the normal occlusion group after measuring mesiodistal tooth sizes of 1173 Han nationals. Nie and Lin[7] compared intermaxillary tooth size discrepancies of 60 subjects who served as the normal occlusion group and 300 patients divided into five malocclusion groups in Chinese population. Similar to Xia and Wu's[18] findings, their results show that tooth size ratios of the malocclusion group are close to those of the normal occlusion group. In the present study, anterior tooth size ratios between the normal occlusion and the malocclusion groups were similar in their pattern of distribution. However, all malocclusion groups show statistically significant higher overall ratios than the normal occlusion group, and the differences were statistically significant.

Significant higher overall ratios of malocclusion groups could be explained by a relatively larger mandibular arch or smaller maxillary arch segments than normal occlusion groups. According to these results, it was thought that there might be an association between malocclusion and tooth sizes.

The frequency of tooth size discrepancy outside 2 SD from Bolton was used as an index of the clinical significance of tooth size imbalance in our sample. It was determined that most of the patients had higher anterior tooth size ratio, especially in Class I; Class II, division 1; and Class III malocclusion groups compared with Bolton 2 SD. However, for overall ratio, most of the values were inside 2 SD of Bolton mean. When comparing the anterior with the overall ratios, it is noted that in every malocclusion group, there is a greater percentage of patients with anterior mesial-distal tooth size discrepancies greater than 2 SD from Bolton mean as compared with patients with overall discrepancies. This could be explained by the fact that anterior teeth, especially the maxillary and mandibular incisors, have a much greater incidence of tooth size deviations and the greatest variables in mesial-distal tooth width occur in the anterior region.

In the present sample, the discrepancy in the anterior and overall ratio outside 2 SD from the Bolton mean amounted to 21.3% and 15.35%, respectively. In other populations, values of 13.4% for overall ratio[6] and 30.6%,[6] 28%,[19] and 22.9%[20] for anterior ratio have been reported in patient populations.

The tooth size and tooth size ratios described by Bolton were different in different racial groups, and the order was Negroids > Mongoloids > Caucasoids.[21] However, there is little data in relation to the degree and frequency of intermaxillary tooth size discrepancy in different racial groups for the same malocclusion category.[19] This study demonstrated the intermaxillary tooth size discrepancies for different malocclusion groups in a Turkish population. Further investigations are needed to explain the probable existing racial differences for intermaxillary tooth size discrepancies in different malocclusion groups and to determine the probable relationships between malocclusion and tooth size measurements.

CONCLUSIONS

On the basis of the results of this investigation, the following conclusions can be drawn:

- Statistically significant sex differences were found only in overall ratio for the normal occlusion group. Significant sexual dimorphism for the malocclusion groups did not exist.
- There were no statistically significant differences among the Class I; Class II, division 1; Class II, division 2; and Class III malocclusion groups for the anterior and overall ratio.
- When tooth size ratios of Class I; Class II, division 1; Class II, division 2; and Class III malocclusion groups were compared with the anterior and overall tooth size ratios of 150 untreated normal occlusion subjects, a statistically significant higher overall ratio was found in the malocclusion patients than in the normal occlusion group.
- There were no statistically significant differences among malocclusion groups; however, there were a large number of patients within each group who had discrepancies greater than 2 SD from the mean.

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