

Intermaxillary tooth size discrepancies among different malocclusion groups

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SUMMARY The aims of this study were to identify possible gender-related differences in tooth size ratios, to determine whether there is a prevalence for intermaxillary tooth size discrepancies in any malocclusion group, and to detect the percentage of tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean. The material comprised the models of 500 subjects (284 females and 216 male aged between 12 and 28 years). Five groups were formed: normal occlusion, Class I, Class II division 1, Class II division 2, and Class III, which had an equal number of subjects. Tooth size measurements were undertaken using an electronic measuring device. Overall, anterior, and posterior ratios were computed as described by Bolton. For statistical evaluation, analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) tests were used.

A significant gender difference was found only for posterior ratio in all groups ($P < 0.01$). There was no significant difference among the malocclusion groups in anterior ratio, but the differences for overall and posterior ratios were significant ($P < 0.05$ and $P < 0.001$, respectively). A large number of subjects had discrepancies greater than 2 SD from Bolton's mean. In addition, the means and SDs in this investigation were found to be larger than those of Bolton. Intermaxillary tooth size ratios may vary in different malocclusion types and may, to some degree, contribute to the severity of a malocclusion.

Introduction

One of the main tasks of an orthodontist is to obtain a functionally balanced occlusion between the upper and lower dental arches. For an ideal occlusion, the mesiodistal crown diameters of the teeth in both arches should correspond. Bolton (1958) investigated the relationship between the mesiodistal crown diameters of the upper and lower teeth and developed an analysis. This analysis is made directly on study casts, and rotations or other malpositions are not taken into account. In the calculation of a possible tooth size discrepancy, the sum of the diameters of the mandibular teeth is divided by that of the maxillary teeth and the result multiplied by 100. For evaluation of the two sets of 12 opposing teeth, the term 'overall ratio' is used and for the two sets of six anterior teeth, the term 'anterior ratio'. Bolton (1958) stated that for a good interdigitation and occlusion, overall ratio should be 91.3 ± 1.91 and anterior ratio 77.2 ± 1.65 . Clinical application of the analysis has been described by Bolton (1962).

Bolton's analysis has been investigated in different racial groups and populations (Lavelle, 1972; Freeman *et al.*, 1996; Nie and Lin, 1999; Santoro *et al.*, 2000; Smith *et al.*, 2000; Ta *et al.*, 2001; Uysal and Sari, 2005; Uysal *et al.*, 2005; Paredes *et al.*, 2006; Endo *et al.*, 2007; Othman and Harradine, 2007; Al-Omari *et al.*, 2008). These investigations were generally carried out on subjects with good or excellent occlusion. A limited number of studies in malocclusion groups have been undertaken, but their results were contradictory (Sperry *et al.*, 1977; Crosby and Alexander, 1989; Nie and Lin, 1999;

Ta *et al.*, 2001; Araujo and Souki, 2003; Laino *et al.*, 2003; Uysal *et al.*, 2005). In addition, gender differences were considered only in the studies of Lavelle (1972), Arya *et al.* (1974), Smith *et al.* (2000), and Uysal and Sari (2005).

Stifter (1958) replicated Bolton's study on Class I occlusion subjects and reported similar results. Lavelle (1972) showed that there was sexual dimorphism in tooth dimensions and in the ratio of upper to lower arch tooth size. Arya *et al.* (1974) observed tooth size differences between genders, in agreement with Moorrees *et al.* (1957), Lysell and Myrberg (1982), Smith *et al.* (2000), and Uysal and Sari (2005).

Sperry *et al.* (1977) analyzed Bolton's ratios for Class I, II, and III subjects and found a mandibular tooth size excess in the overall ratio of the Class III patients, while Crosby and Alexander (1989) found no difference in tooth size in different malocclusion groups (Class I, Class II division 1, Class II division 2, and Class II surgery). Nie and Lin (1999) carried out a similar study on normal occlusion and malocclusion groups (Class I with bimaxillary protrusion, Class II division 1, Class II division 2, Class III, and Class III surgery) but found no sexual dimorphism for these ratios in any of the groups, and no significant difference between the subcategories of the malocclusion groups. However, they observed significant differences among the ratios of the Class I, II, and III groups. The subjects with a Class III malocclusion had larger ratio values than the other groups.

Uysal *et al.* (2005) found no significant sexual dimorphism except in the normal occlusion group in overall ratio; there

were no statistically significant differences among the malocclusion groups for anterior and overall ratios.

The aims of the present study were (1) to identify possible gender-related differences in tooth size ratios, (2) to determine whether there is a difference in intermaxillary tooth size discrepancies among the malocclusion groups classified by dental and skeletal variables, and (3) to determine the percentage of tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean.

Subjects and methods

The sample comprised the study models of 100 subjects with normal occlusion and 400 patients with varying malocclusions. The distribution of the subjects according to gender and malocclusion is shown in Table 1. The models were randomly selected from the archives of the Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey. The normal occlusion group included those with ideal occlusion and well-balanced faces. All subjects were between 12 and 28 years of age and of Turkish origin with Turkish grandparents. Occlusal categories, classified by Angle classification, coincided with the skeletal categories. Skeletal diagnosis was made on the basis of ANB angle; in skeletal Class I, ANB angle was from 0 to 5 degrees, for skeletal Class II more than 5 degrees, and for skeletal Class III less than 0 degrees (Laino *et al.*, 2003; Uysal *et al.*, 2005). The subjects were divided into five

equal groups: normal occlusion, Class I, Class II division 1, Class II division 2, and Class III.

The following study model selection criteria were used:

1. Good quality models of the normal occlusion and pre-treatment models of the malocclusion groups.
2. All permanent teeth erupted except second and third molars.
3. No mesiodistal or occlusal tooth abrasion.
4. No residual crown or crown-bridge restoration.
5. Absence of tooth anomalies regarding form, structure, and development.

A RMI 550 three-dimensional measuring device (SAM Präzisionstechnik GmbH, München, Germany) was used to measure the casts to the nearest 0.01 mm (Figure 1). The mesiodistal crown diameters of all teeth were measured according to the method described by Moorrees *et al.* (1957), i.e. from the mesial contact point to the distal contact point at the greatest interproximal distance. The individual tooth diameters were summed to derive the anterior (canine to canine), posterior (first molar to first premolar), and overall (first molar to first molar) arch segments. The segments were used to define the following ratios:

1. Overall ratio: overall mandibular arch segment divided by the overall maxillary arch segment.
2. Anterior ratio: anterior mandibular arch segment divided by the anterior maxillary arch segment.
3. Posterior ratio: posterior mandibular arch segment divided by the posterior maxillary arch segment.

Overall, anterior, and posterior ratios were computed for all subjects whose values were outside 1 or 2 SDs from the mean value.

To determine the errors associated with the measurements, 30 study casts were randomly selected. Their measurements were repeated 4 weeks after the first measurement by the same examiner (EU). The first and second measurements were compared as described by Houston (1983). Coefficients of reliability were computed as 0.981, 0.990, and 0.965 for overall, anterior, and posterior ratios, respectively. The results showed that the measurements could be repeated with high accuracy.

In order to determine whether there was sexual dimorphism in the incidence of intermaxillary tooth size discrepancy and to compare intermaxillary tooth size discrepancies among the groups, analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test were applied. Statistical analyses were carried out using the Statistical Package for Social Sciences (Version 11.5, SPSS Inc., Chicago, Illinois, USA).

Results

The means and SDs of the tooth size ratios for each gender and occlusion group are summarized in Table 2. Table 3 shows the results of ANOVA. A statistically significant

Table 1 The number of subjects in each gender and malocclusion group.

Malocclusion groups	Female	Male	Total
Normal occlusion	39	61	100
Class I	65	35	100
Class II division 1	61	39	100
Class II division 2	63	37	100
Class III	58	42	100
Total	284	216	500

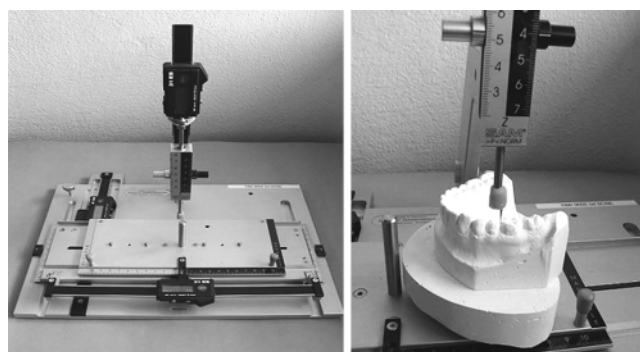


Figure 1 The electronic measuring device.

gender difference was found only for posterior ratio ($P < 0.01$). As there was no sexual dimorphism in overall and anterior ratios, males and females were combined for each malocclusion groups for these ratios. Comparisons between the male and female subjects indicated larger posterior ratio values for males in all groups except Class III.

ANOVA demonstrated that there were statistically significant differences among the malocclusion groups for overall and posterior ratios ($P < 0.05$ and $P < 0.001$, respectively; Table 3). The results of Tukey's HSD analysis, which was used for comparisons of tooth size ratios of different malocclusion groups, are presented in Table 4. For overall ratio, the difference between the Class II division 1 and Class III groups was statistically significant ($P < 0.01$). For the posterior ratio, the differences between the normal occlusion and Class I groups and between the normal occlusion and Class III groups were statistically significant at the 0.05 and 0.001 levels, respectively. Other differences among the groups were not statistically significant. The highest ratio values were in the Class III group, i.e. the subjects with a Class III malocclusion had larger mandibular teeth.

The frequencies of tooth size discrepancy 1, 2, and more than 2 SDs from Bolton's mean for overall and anterior ratios of all groups are presented in Table 5. For overall ratio in the total sample, 61.6 per cent were inside 1 SD, 28.4 per cent inside 2 SD, and 11 per cent outside 2 SD. The percentage distributions for anterior ratio were 41.4, 30.4, and 28.2 per cent, respectively.

Discussion

It has been commonly accepted that the mesiodistal crown diameters of the upper and lower teeth should match each other for a balanced occlusion. Significant higher overall ratios can be explained by relatively larger mandibular or smaller maxillary arch segments, and thus there might be an association between malocclusion and tooth size. In other words, tooth size discrepancies between maxillary and mandibular teeth may be an important factor in the cause of malocclusions (Othman and Harradine, 2006).

In order to predict the occlusal relationships at the end of orthodontic treatment, a number of studies have been carried out. Many investigators have attempted to quantify interarch tooth size discrepancies, but none are as useful or as well accepted as Bolton's analysis (White, 1982; Crosby and Alexander, 1989; Shellhart *et al.*, 1995; Freeman *et al.*, 1996; Smith *et al.*, 2000). According to Sheridan (2000), the vast majority of orthodontists (91 per cent) use Bolton's tooth size analysis. This analysis has been investigated in different racial and malocclusion groups (Lavelle, 1972; Arya *et al.*, 1974; Crosby and Alexander, 1989; Freeman *et al.*, 1996; Nie and Lin, 1999; Santoro *et al.*, 2000; Smith *et al.*, 2000; Ta *et al.*, 2001; Araujo and Souki, 2003; Uysal and Sari, 2005; Uysal *et al.*, 2005; Paredes *et al.*, 2006; Endo *et al.*, 2007; Othman and Harradine, 2007; Al-Omari

Table 2 Tooth size ratios [mean (X) and standard deviation (SD)] for the groups.

	Female		Male		Pooled	
	X	SD	X	SD	X	SD
Normal occlusion						
Overall ratio	91.63	2.04	92.39	1.84	92.10	1.95
Anterior ratio	79.17	2.65	79.35	2.47	79.28	2.53
Posterior ratio	103.49	2.54	104.98	2.63		
Class I malocclusion						
Overall ratio	92.24	2.32	92.33	1.88	92.27	2.16
Anterior ratio	78.58	3.01	78.66	2.41	78.61	2.80
Posterior ratio	105.53	2.81	105.85	2.92		
Class II division 1 malocclusion						
Overall ratio	91.64	2.07	92.22	2.05	91.86	2.07
Anterior ratio	78.38	2.46	78.30	2.17	78.35	2.34
Posterior ratio	104.56	3.09	105.99	3.07		
Class II division 2 malocclusion						
Overall ratio	92.16	2.26	92.42	2.15	92.26	2.22
Anterior ratio	79.11	2.69	78.76	2.67	78.98	2.67
Posterior ratio	104.88	3.08	105.82	3.05		
Class III malocclusion						
Overall ratio	92.92	1.83	92.81	2.05	92.87	1.92
Anterior ratio	79.24	2.83	79.39	3.13	79.30	2.94
Posterior ratio	106.11	2.57	105.87	2.12		

Table 3 The results of analysis of variance.

Parameters	Factors	df	F	P
Overall ratio	Groups	4	3.020	0.018
	Gender	1	2.761	0.097
	Interaction	4	0.701	0.592
Anterior ratio	Groups	4	2.307	0.570
	Gender	1	0.000	0.985
	Interaction	4	0.161	0.958
Posterior ratio	Groups	4	5.316	0.000
	Gender	1	9.221	0.003
	Interaction	4	1.661	0.158

df, degree of freedom.

et al., 2008). The present study was carried out on Turkish subjects. Both skeletal classification, according to ANB, and Angle's dental classification were used for determination of the groups, and all malocclusions in the sagittal direction were included.

ANB is affected by several factors in the craniofacial structures (Oktay, 1991; Hurmerinta *et al.*, 1997), and thus floating norms have been introduced for ANB angle (Järvinen, 1986). In order to overcome the limitations of this angle, the selection criteria in the present study included Class II patients with ANB angle greater than 5 degrees and Class III patients with an ANB less than 0 degrees similar to the studies of Laino *et al.* (2003) and Uysal *et al.* (2005).

Table 4 Differences between the groups for overall, anterior, and posterior ratios and their levels of significance determined by Tukey's honestly significant difference analysis.

Comparisons	Overall ratio		Anterior ratio		Posterior ratio	
	Mean difference	<i>P</i>	Mean difference	<i>P</i>	Mean difference	<i>P</i>
Normal occlusion–Class I	–0.17	0.976	0.67	0.390	–1.25	0.016
Normal occlusion–Class II division 1	0.23	0.932	0.94	0.101	–0.72	0.370
Normal occlusion–Class II division 2	–0.16	0.981	0.30	0.932	–0.83	0.226
Normal occlusion–Class III	–0.78	0.063	–0.19	1.000	–1.61	0.001
Class I–Class II division 1	0.41	0.634	0.26	0.958	0.53	0.677
Class I–Class II division 2	0.01	1.000	–0.37	0.865	0.41	0.836
Class I–Class III	–0.60	0.242	–0.69	0.361	–0.36	0.892
Class II division 1–Class II division 2	–0.40	0.657	–0.63	0.454	–0.11	0.999
Class II division 1–Class III	–1.00	0.006	–0.95	0.089	–0.89	0.168
Class II division 2–Class III	–0.61	0.225	–0.32	0.916	–0.78	0.291

Bold font indicates statistically significant differences.

Table 5 The percentage distribution of anterior and overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's means.

	Anterior ratio						
	Outside 2 SD (%)	2 SD (%)	1 SD (%)	Mean (%)	1 SD (%)	2 SD (%)	Outside 2 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	0	5	12	3	26	26	28
Class I malocclusion	3	6	22	2	16	27	24
Class II division 1 malocclusion	4	5	23	1	26	23	18
Class II division 2 malocclusion	3	6	17	1	18	28	27
Class III malocclusion	4	4	14	2	24	22	30
	Overall ratio						
	Outside 2 SD (%)	2 SD (%)	1 SD (%)	Mean (%)	1 SD (%)	2 SD (%)	Outside 2 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	2	6	25	3	39	18	7
Class I malocclusion	1	5	27	3	33	22	9
Class II division 1 malocclusion	1	11	29	1	36	15	7
Class II division 2 malocclusion	1	11	21	3	30	25	9
Class III malocclusion	0	3	18	1	39	26	13

Needle-pointed orthodontic dividers are commonly used to determine the greatest mesiodistal diameter of the teeth. Digital callipers are also used to measure the teeth to the nearest 0.1 or 0.01 mm. In recent years, new techniques and devices have been developed in order to achieve more accurate and reliable tooth measurements (Yen, 1991; Schirmer and Wiltshire, 1997; Mok and Cooke, 1998; Nie and Lin, 1999; Tomasetti *et al.*, 2001; Othman and Harradine, 2006). All tooth measurements in this study were carried out using an electronic measuring device. This device has a needle-pointed measuring rod which can move in three dimensions of space, allowing the greatest

mesiodistal diameters of the teeth to be easily measured, even if crowding is present.

Moorrees *et al.* (1957) showed gender differences in overall ratio. Lavelle (1972) reported relatively larger overall and anterior ratios in males compared with white, black, and mongoloid female populations. Smith *et al.* (2000) found larger overall and posterior ratios in black, Hispanic, and white males. Uysal and Sarı (2005) found statistically significant gender difference only in overall ratio. Crosby and Alexander (1989) did not differentiate between genders and did not mention whether there was

sexual dimorphism for tooth size ratios in their sample. Santoro *et al.* (2000), Ta *et al.* (2001), Basaran *et al.* (2006), Endo *et al.* (2007), and Al-Omari *et al.* (2008) on the other hand observed no sexual dimorphism in overall and anterior ratios. Nie and Lin (1999) found no difference between the genders for the three tooth size ratios. The results of the present study showed no sexual dimorphism in overall and anterior ratios but sexual dimorphism in the posterior ratio ($P < 0.01$; Table 3). For this reason, males and females were combined only for comparison of overall and anterior ratios.

Different results have been reported in the literature regarding tooth size ratios in different malocclusion groups. Xia and Wu (1983) found no statistically significant difference in tooth size ratios between malocclusion and normal occlusion groups. Crosby and Alexander (1989), in a comparison of tooth size ratios among Class I, Class II division 1, Class II division 2, and Class II surgery groups, found no significant differences. The present study showed that only anterior ratio was not significantly different among the groups (Table 4). The possible reason for these different results may be ethnic or racial because tooth sizes show considerable variation in different racial and occlusal categories (Lavelle, 1972).

Sperry *et al.* (1977) observed, in a Class III group with mandibular prognathism, more mandibular tooth size excess for overall ratio than in the Class I and Class II groups. Similarly, Lavelle (1972) and Nie and Lin (1999) demonstrated that Class III subjects were characterized by smaller maxillary tooth dimensions and larger mandibular teeth. Araujo and Souki (2003) investigated the correlations between anterior tooth size discrepancies and Angle Class I, II, and III malocclusions. They concluded that Angle Class I and III individuals showed a significantly greater prevalence of tooth size discrepancies than those with a Class II malocclusion, and that the mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and II subjects. Othman and Harradine (2006) reviewed the literature on Bolton's tooth size discrepancy and concluded that subjects with a Class III malocclusion probably had higher average ratios.

In the present study, there were significant differences among the normal occlusion and malocclusion groups for overall and posterior ratios ($P < 0.05$ and $P < 0.001$, respectively; Table 3). The results of Tukey's HSD analysis showed that the Class III group had the largest overall, anterior, and posterior ratios, but statistical significance was seen only between the Class II division 1 and Class III groups for overall ratio ($P < 0.01$), between the normal occlusion and Class III groups ($P < 0.001$), and between the normal occlusion and Class I groups ($P < 0.05$) for posterior ratio (Table 4). There was a tendency for mandibular tooth size excess in the Class III malocclusion subjects and for maxillary tooth size excess in the Class II malocclusion patients. These results are compatible with the literature.

According to Bolton (1962), a ratio greater than 1 SD from the reported mean values indicates a need for diagnostic

consideration. Crosby and Alexander (1989) and Freeman *et al.* (1996) defined a significant discrepancy as a value of more than 2 SDs from Bolton's mean. On the other hand, Othman and Harradine (2006) stated that Bolton's SDs were not a good guide to the prevalence of a clinically significant tooth size discrepancy.

In the present sample, the frequency of tooth size discrepancy outside 1 or 2 SDs from Bolton's mean values was used to determine the clinical significance of tooth size imbalance. The results for overall and anterior ratios were nearly the same. Most subjects in all groups had overall and anterior ratios within a 1 SD interval (Table 5). It should be noted, however, that the 11 per cent of the subjects had a discrepancy greater than 2 SDs from Bolton's means for overall ratio and 28.2 per cent for anterior ratio. Thus maxillary and mandibular anterior teeth had a greater incidence of tooth size deviations, i.e. the greatest variables in mesiodistal tooth width occurred in the anterior region. It should also be noted that there was a larger percentage of subjects with mandibular tooth size excess since almost all those with ratios outside 2 SDs had larger ratio values than Bolton's means. In other studies, percentage values of 9.5 (Al-Omari *et al.*, 2008), 11 (Santoro *et al.*, 2000), 13.4 (Freeman *et al.*, 1996), and 15.3 (Uysal *et al.*, 2005) for overall ratio and of 21.3 (Uysal *et al.*, 2005), 22.9 (Crosby and Alexander, 1989), 23.7 (Al-Omari *et al.*, 2008), 28 (Santoro *et al.*, 2000), and 30.6 (Freeman *et al.*, 1996) for anterior ratio have been reported in different patient populations. The present results are compatible with those in the literature.

For both overall and anterior ratios in the present study, the means and SDs were larger than in Bolton's (1958) study. This finding is consistent with the results of Nie and Lin (1999), Smith *et al.* (2000), and Al-Omari *et al.* (2008). Crosby and Alexander (1989), Freeman *et al.* (1996), and Santoro *et al.* (2000) found that the means in their studies and those of Bolton's study were nearly identical although the ranges and SDs were significantly larger. The probable reason for these findings may be the types of population that constituted the samples.

Conclusions

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

1. Statistically significant gender differences were found only for posterior ratio. The gender differences in overall and anterior ratios were not significant.
2. There were no statistically significant differences among the groups for anterior ratio.
3. There were statistically significant differences among the groups for overall and posterior ratios. The significance originated from the Class III group.
4. A large number of subjects in each group had discrepancies greater than 2 SD from the Bolton mean.

The cause of these discrepancies was the larger mesiodistal diameter of the mandibular teeth.

5. The means and SDs for overall and anterior ratios in the present study were larger than those in Bolton's study.

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