Original Article

Tooth Size Discrepancies among Different Malocclusions in a Japanese Orthodontic Population

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ABSTRACT

Objective: To identify the possible sex differences in anterior and overall tooth size ratios and to evaluate whether any differences exist in tooth size ratios and distributions of subjects with clinically significant tooth size discrepancies among Angle Class I, Class II, and Class III malocclusion groups with the corresponding skeletal characteristics in a Japanese population.

Materials and Methods: Each malocclusion group comprised 60 subjects (30 males and 30 females). The mesiodistal width from first molar to first molar was measured on each pretreatment cast to the nearest 0.01 mm using digital calipers, and the anterior and overall ratios were calculated. Student's *t*-test, Welch *t*-test, analysis of variance, and χ^2-test were performed for statistical analysis.

Results: No statistically significant sex differences were found in anterior or overall ratio in any group. No significant differences in anterior or overall ratios were found among the malocclusion groups. No significant differences were found between the distributions of subjects with clinically significant tooth size discrepancies, categorized by the Bolton standard deviation definition and by the actual amount of change calculated for tooth size correction in millimeters, among the malocclusion groups except for the mandibular correction for the overall ratio between Class I and Class III subjects.

Conclusion: Bolton's values can be used with confidence for the typical Japanese orthodontic population. The use of the actual millimeters of correction for the tooth size ratios could help orthodontists avoid underestimating the prevalence of clinically significant tooth size discrepancies.

KEY WORDS: Anterior ratio; Overall ratio; Tooth size discrepancy; Malocclusion; Japanese population

INTRODUCTION

An appropriate balance of mesiodistal tooth widths between maxillary and mandibular arches is needed to achieve the best possible esthetic and functional results at the completion of orthodontic treatment.[1] Although there have been a few published studies describing interarch tooth size proportions,[2] Bolton's anterior and overall tooth size ratios have been most commonly accepted as essential diagnostic criteria in orthodontics since Bolton published his tooth size studies.[1,3] Bolton established ideal anterior and overall ratios with mean values of 77.2% and 91.3%, respectively, for proper harmony of maxillary and mandibular teeth.[1,3]

Several pieces of evidence indicate that tooth size ratios show ethnic, racial and sex differences.[4,5] Lavell[4] reported that Negroids had greater overall and anterior ratios than Caucasoids and Mongoloids, and that the overall ratio was consistently greater in males than in females, regardless of racial origin. Smith et al[5] concluded that Bolton's ratios were only applicable to white females and therefore should not be applied indiscriminately to white males, blacks, or Hispanics. Smith et al[5] also concluded that the overall ratio was significantly larger in males than in females.

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Accepted: December 2007. Submitted: October 2007.

 DOI: 10.2319/101007-486.1

Some studies have shown statistically significant associations between tooth size ratios and malocclusion groups.[6–9] Nie and Lin[6] found significant differences in the anterior and overall ratios between the malocclusion groups in a Chinese population, the ratios showed that the order was Class III > Class I > Class II. Ta et al[7] reported that although the anterior ratios showed no significant differences among Class I, Class II, and Class III malocclusion groups in a Hong Kong population, the overall ratios were significantly greater in Class III than Class II malocclusion groups. Araujo and Souki[8] concluded that the mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and Class II subjects in a Brazilian population. Fattahi et al[9] showed that the anterior ratio of the Class III group was significantly greater than those of Class II division 1 and Class II division 2 groups in an Iranian population, and that the overall ratio of the Class III group was significantly greater than the other groups. However, some studies have demonstrated no significant differences in tooth size ratios among different Angle malocclusion groups in different populations.[10–13]

A PubMed search in July 2007 with the search subject ''tooth size discrepancy'' found no English references available regarding the association between Bolton's tooth size ratios and malocclusions in a Japanese population. The objectives of this study were to identify possible sex differences in anterior and overall tooth size ratios and to evaluate whether any differences exist in tooth size ratios and distributions of subjects with tooth size discrepancies among Angle Class I, Class II, and Class III malocclusion groups with the corresponding skeletal characteristics in a Japanese population.

MATERIALS AND METHODS

The sample for this study consisted of 180 subjects subdivided into three types of malocclusion. All the subjects were homogeneous Japanese. The subjects with varying malocclusions were selected retrospectively from a list of orthodontic patients who had received treatment at the clinics in the Nippon Dental University Niigata Hospital (Niigata, Japan). They fell into any one of the three malocclusion groups and met the selection criteria of the casts as described later. The three malocclusion groups were Class I malocclusion, Class II malocclusion, and Class III malocclusion. In the malocclusion groups, the occlusion categories, which were classified according to the Angle classification, coincided with skeletal categories. Skeletal types were assessed cephalometrically by the ANB angle: Class I, from 1.2 to 5.4° for males, and from 0.9 to 4.3° for females; Class II, >5.4° for males and >4.3° for females; and Class III, <1.2° for males and <0.9° for females. These divisions were made based on the study by the Japanese Society of Pediatric Dentistry, which reported that the Japanese norms of the ANB angle were 3.3° for males (SD = 2.1°) and 2.6° (SD = 1.7°) for females.[14] Each malocclusion group consisted of 30 males and 30 females. The selection criteria of the casts in the malocclusion groups were as follows: (1) a fully erupted permanent dentition with only the third molars being absent; (2) good-quality pretreatment casts; (3) no tooth agenesis or extractions; (4) no mesiodistal restorations or abrasion; and (5) no tooth anomalies.

Digital calipers were used to measure the mesiodistal widths from first molar to first molar to the nearest 0.01 mm. The mesiodistal width of each tooth was measured at the greatest distance between the contact points on the proximal surfaces. All the measurements were done by one investigator. The anterior and overall ratios were calculated for each cast using the method described by Bolton.[1,3]

To ensure measurement accuracy, 1 month later 30 pairs of dental casts were randomly selected from the malocclusion groups and the mesiodistal tooth widths were again measured by the same investigator. The anterior and overall ratios were calculated using the same method. A paired *t*-test was applied to the first and second measurements. No statistically significant differences were found between the first and second measurements of 30 pairs of dental casts ($P > .05$). Random error was determined by calculating the standard deviation of the differences between the first and second measurements.[15] The random errors of the anterior and overall ratio were 0.59% and 0.61%, respectively, which are unlikely to spoil the significant results in this study.

Calculations were made to see the distributions of subjects with anterior and overall tooth size discrepancies outside two standard deviations from the Bolton means and more than 1.5 mm of maxillary or mandibular correction. These measures are required to give the Bolton mean anterior and overall ratios.

Statistical Analysis

Statistical analyses were performed with the software Stat Mate (ATMS, Tokyo, Japan). The means, standard deviations, standard errors, and ranges of the anterior and overall ratios were calculated separately for males and females in the different malocclusion groups. To determine whether there were sex differences in the anterior and overall ratios in each malocclusion group, Student's *t*-test or Welch's *t*-test was used after testing the homogeneity of the variances. As there were no significant sex differences, the an-

Table 1. Anterior and overall tooth size ratios (%) by sex and malocclusion form

Group	Male				Female				*t*-test[a]
	Mean	SD	SE	Range	Mean	SD	SE	Range	
Anterior ratio									
Class I malocclusion	77.63	1.82	0.33	73.22–80.96	77.33	2.49	0.45	72.15–81.08	NS
Class II malocclusion	77.92	2.26	0.41	71.75–81.51	77.93	2.29	0.42	73.04–83.92	NS
Class III malocclusion	77.54	1.92	0.35	74.00–80.65	78.20	2.40	0.44	71.13–83.55	NS
Overall ratio									
Class I malocclusion	91.14	2.09	0.38	87.11–96.36	90.88	2.20	0.40	86.77–95.51	NS
Class II malocclusion	91.43	1.98	0.36	87.79–95.14	91.17	1.91	0.35	86.73–94.71	NS
Class III malocclusion	91.46	1.46	0.27	87.41–94.61	91.83	2.20	0.40	86.27–97.40	NS

[a] NS indicates not significant.

terior and overall ratios in males and females were combined. The combined mean ratios were compared with those from Bolton's study,[1,3] by using Student's *t*-test or Welch's *t*-test after the homogeneity of the variance was tested. A one-way analysis of variance was performed to determine statistically significant differences in the combined male and female mean ratios among the malocclusion groups. In addition, χ^2-tests were performed to test significant differences in the distribution of subjects with anterior and overall tooth size discrepancies among the malocclusion groups.

RESULTS

Table 1 shows that no statistically significant differences between the sexes in either anterior or overall ratio were found in each malocclusion group. Therefore, the values for males and females were combined for all other analyses.

Table 2 shows that no statistically significant differences were found in the anterior or overall ratios for every malocclusion group from the Bolton standards except for the anterior ratio for the Class II malocclusion group. The table also shows that there were no significant differences in anterior or overall ratios among the malocclusion groups.

Table 3 shows that significant anterior and overall tooth size discrepancies outside two standard deviations from the Bolton means were found in 14.4% and 6.7% of all the malocclusion subjects, respectively. The χ^2-tests demonstrated no significant differences in the distribution of subjects with anterior or overall tooth size discrepancies among the malocclusion groups.

Table 4 shows that for the anterior correction, a maxillary correction of more than $\pm$1.5 mm was needed in 29.4% of all the malocclusion subjects if the mandibular tooth size were to be considered normal, while the corresponding figure for the mandibular corrections was 17.2% if the maxillary tooth size were to be considered normal. Similarly, for the overall correction, the maxillary and mandibular corrections were needed in 43.9% and 40% of all the malocclusion subjects, respectively. However, χ^2-tests demonstrated no significant differences in the distribution of subjects with anterior or overall corrections among the malocclusion groups, except the mandibular correction for the overall tooth size discrepancy between Class I and Class III malocclusion groups.

DISCUSSION

In this study, there were no statistically significant differences between the sexes in anterior or overall

Table 2. Tooth size ratios of each malocclusion group compared with Bolton's figures

Group	Mean	SD	SE	Range	*t*-test[a]	ANOVA[a]
Anterior ratio						
Bolton	77.2	1.65	0.22	74.5–80.4	—	—
Class I malocclusion	77.48	2.17	0.28	72.15–81.08	NS	
Class II malocclusion	77.93	2.25	0.29	71.75–83.92	$P < .05$	NS
Class III malocclusion	77.87	2.18	0.28	71.13–83.55	NS	
Overall ratio						
Bolton	91.3	1.91	0.26	87.5–94.8	—	—
Class I malocclusion	91.01	2.13	0.28	86.77–96.36	NS	
Class II malocclusion	91.30	1.94	0.25	86.73–95.14	NS	NS
Class III malocclusion	91.65	1.86	0.24	86.27–97.40	NS	

[a] NS indicates not significant.

Table 3. Distribution of subjects with anterior and overall tooth size discrepancies

Group	Anterior Ratio No. (%)		
	Outside −2 SD <73.89	(−2 SD) – (+2 SD) 73.90–80.50	Outside +2 SD >80.51
Class I malocclusion	4 (6.67)	54 (90.00)	2 (3.33)
Class II malocclusion	3 (5.00)	49 (81.67)	8 (13.33)
Class III malocclusion	1 (1.67)	51 (85.00)	8 (13.33)
Total malocclusions	8 (4.44)	154 (856)	18 (10.00)
	Overall ratio No. (%)		
	Outside 2 SD <87.47	(−2 SD) – (+ 2 SD) 87.48–95.12	Outside 2 SD >95.13
Class I malocclusion	4 (6.67)	54 (90.00)	2 (3.33)
Class II malocclusion	2 (3.33)	57 (95.00)	1 (1.67)
Class III malocclusion	2 (3.33)	57 (95.00)	1 (1.67)
Total malocclusions	8 (4.44)	168 (93.33)	4 (2.22)

ratio for each malocclusion group. These findings are in agreement with those of previous studies on several other populations.[6,7,11–13] However, the findings are inconsistent with those of Fattahi et al,[9] who analyzed tooth size ratios of Angle Class I, Class II division 1, Class II division 2, and Class III groups with the corresponding skeletal characteristics in an Iranian population and demonstrated significant sex differences in the anterior ratio among the malocclusion groups, but not the overall ratio. Some other investigations showed statistically significant differences between the sexes in the overall ratio for the malocclusion groups[5] and the normal occlusion group[11] among different populations. It is, therefore, speculated that sex differences in tooth size ratios may be population specific.

Our results for the significant difference in the anterior ratio between the Class II malocclusion group and Bolton's subjects suggested that the Bolton anterior ratio was not applicable to the Japanese patients with Class II malocclusion. Similar findings were obtained from our previous study, which led us to conclude that the Bolton anterior ratio was not applicable to Japanese with good occlusions.[16] However, the difference of 0.73% in the mean anterior ratio between our Class II malocclusion group and Bolton's subjects corresponded to either a maxillary correction of 0.33 mm or a mandibular correction of −0.42 mm, thus demonstrating that this difference could not be clinically significant because Proffit[17] stated that tooth size discrepancies of <1.5 mm were rarely significant. Therefore, Bolton's values can be used with confidence in the typical Japanese orthodontic population.

The larger standard deviations of both anterior and overall ratios for our subjects than for Bolton's subjects might have been caused by the fact that all of our subjects had malocclusions and Bolton's subjects had excellent occlusion.

Mongoloids, included the Japanese population, differ from Caucasoids by having a high prevalence of shovel-shaped incisors,[18] which increase an incisor thickness. Our results could not support those of Rudolph et al,[19] who demonstrated that the anterior ratio decreased with increasing the incisor thickness.

The results of this study support the findings of Uysal et al,[11] who also found no significant differences in anterior or overall ratio when comparing Angle Class

Table 4. Ratios of subjects requiring anterior and overall tooth size corrections

Group	<(−1.51)		(−1.50) −0.00		0	0.01–1.50		>1.51	
	Maxilla	Mandible	Maxilla	Mandible		Maxilla	Mandible	Maxilla	Mandible
Anterior Correction No. (%)									
Class I malocclusion	6 (10.00)	3 (5.00)	18 (30.00)	32 (53.34)	1 (1.67)	21 (35.00)	20 (33.33)	14 (23.33)	4 (6.67)
Class II malocclusion	5 (8.33)	10 (16.67)	13 (21.67)	32 (53.34)	0 (0.00)	29 (48.33)	14 (23.33)	13 (21.67)	4 (6.67)
Class III malocclusion	6 (10.00)	8 (13.33)	18 (30.00)	28 (46.67)	0 (0.00)	27 (45.00)	22 (36.67)	9 (15.00)	2 (3.33)
Total malocclusions	17 (9.44)	21 (11.67)	49 (27.22)	92 (51.11)	1 (0.56)	77 (42.78)	56 (31.11)	36 (20.00)	10 (5.56)
Overall Correction No. (%)									
Class I malocclusion	19 (31.67)	12 (20.00)	15 (25.00)	14 (23.33)	0 (0.00)	14 (23.33)	15 (25.00)	12 (20.00)	19 (31.67)
Class II malocclusion	12 (20.00)	12 (20.00)	15 (25.00)	21 (35.00)	0 (0.00)	19 (31.67)	16 (26.67)	14 (23.33)	11 (18.33)
Class III malocclusion	8 (13.33)	11 (18.33)	14 (23.33)	27 (45.00)	0 (0.00)	24 (40.00)	15 (25.00)	14 (23.33)	7 (11.67)
Total malocclusions	39 (21.67)	35 (19.44)	44 (24.44)	62 (34.44)	0 (0.00)	57 (31.67)	46 (25.56)	40 (22.22)	37 (20.56)

I, Class II division 1, Class II division 2, and Class III malocclusion subjects with the corresponding ANB angles. Crosby and Alexander,[10] Al-Khateeb and Abu Alhaija,[12] and Akyalcin et al[13] showed no significant differences in anterior or overall ratio among the malocclusion groups, as confirmed in this study, but they had minor differences in sample selections from our study. The study by Crosby and Alexander[10] was made up of four groups of subjects: Angle Class I, Class II division 1, Class II division 2, and Class II subjects. It neither included patients with Class III malocclusion nor differentiated between sexes. The subjects of the last group alone were those who had to have surgery. Al-Khateeb and Abu Alhaija[12] analyzed Angle Class I, Class II division 1, Class II division 2, and Class III malocclusion groups in a Jordanian population, whereas Akyalcin et al[13] included in their Turkish study sample Angle Class I, Class II, and Class III subjects with a skeletal Class I jaw relationship. Crosby and Alexander,[10] Al-Khateeb and Abu Alhaija,[12] and Ta et al,[7] did not mention the relationship of malocclusion to skeletal patterns. Part of our results are consistent with those reported by Ta et al,[7] who demonstrated no significant differences in the anterior ratio among Angle Class I, Class II, and Class III malocclusion groups in a Honk Kong population and a significant difference in the overall ratio between Class II and Class III malocclusion groups.

Our results are in disagreement with Nie and Lin,[6] Araujo and Souki,[8] and Fattahi et al,[9] who reported statistically significant differences in tooth size ratios among different Angle malocclusion groups. They showed a tendency toward greater tooth size ratios among subjects with Class III malocclusion than among those with other classes of malocclusion in Chinese,[6] Brazilian[8] and Iranian[9] populations. The probable reason for these different results might be population and malocclusion specific.

In this study, the ratios outside two standard deviations from Bolton's mean were defined as values indicating clinically significant tooth size discrepancy, as used in other investigations.[7,8,10,11,16,20,21] Our results suggesting no significant differences in the distribution of anterior or overall tooth size discrepancy categorized by standard deviations of Bolton values among the malocclusion groups are consistent with those reported by Araujo and Souki,[8] Crosby and Alexander,[10] and Akyalcin et al.[13] Araujo and Souki [8] and Akyalcin et al[13] used the ratios outside one standard deviation from Bolton's mean as tooth size discrepancy; Crosby and Alexander[10] used the ratios outside two standard deviations. The prevalence rate of the clinically significant anterior tooth size discrepancy using the Bolton standard deviation definition was 14.4% in our sample. This rate is smaller than those reported in other orthodontic populations by Othman and Harradine[15] (17.4%), Araujo and Souki[8] (22.7%), Crosby and Alexander[10] (22.9%), Freeman et al[20] (30.6%), and Santoro et al[21] (28%). On the other hand, a clinically significant overall tooth size discrepancy was found in 7.6% of the Japanese orthodontic population, which is similar to the prevalence rate found in an orthodontic population by Othman and Harradine[15] (5.4%) and smaller than those found by Freeman et al[20] (13.4%) and Santoro et al[21] (11%). Our findings of lower prevalence rates of clinically significant discrepancy for the overall ratio than for the anterior ratio are supported by some previous studies,[15,20,21] which may be explained by the fact that anterior teeth have much greater tooth size deviations, especially in the subjects with malocclusion.

Some studies demonstrated that the actual amount of discrepancy expressed in millimeters provides orthodontists with more useful information on the correction for clinically significant tooth size discrepancy than the ratio in percentage terms.[15,22] In this study, as well as in previous studies,[15,22] 1.5 mm was taken as an appropriate threshold for a clinically significant discrepancy. This figure was based on the statement by Proffit.[17] Our results showed that there was only a significant difference in the distribution of subjects requiring mandibular corrections for overall tooth size discrepancy expressed in millimeters between Class I and Class III malocclusion groups; this demonstrates that more subjects needed mandibular correction in the Class I malocclusion group than in the Class III malocclusion group. In our study, 29.4% and 17.2% of the sample required the maxillary and mandibular corrections for anterior ratio, respectively, while the corresponding figures for overall correction were 43.9% and 40.0%. Our findings using the millimetric definition showed that the prevalence rates of subjects with clinically significant tooth size discrepancies were much higher than those in the Bolton study for the maxillary correction of anterior ratios and the maxillary and mandibular corrections of overall ratios, and yet they were similar for the mandibular correction of anterior ratios, as confirmed by Othman and Harradine.[15] These finding suggest that the prevalence of clinically significant tooth size discrepancy might have been underestimated by the use of the Bolton standard deviation definition and might have been different based on the method of expressing the discrepancy and the arch selected for correction, thus supporting the findings by Othman and Harradine[15] and Bernabe et al.[22]

CONCLUSIONS

- No statistically significant sex differences were found in anterior or overall ratios in each malocclusion group.

- No significant differences in anterior or overall ratio were found among the malocclusion groups.
- No significant differences in the distribution of subjects with clinically significant tooth size discrepancies, categorized by the Bolton standard deviation definition and by the actual amount of change calculated for tooth size correction in millimeters, were found among the malocclusion groups except for the mandibular correction for overall ratios between Class I and Class III subjects.
- Bolton's values can be used with confidence in a Japanese orthodontic population.
- The use of the actual millimeters of correction for the tooth size ratios could help orthodontists avoid underestimating the prevalence of clinically significant tooth size discrepancy.

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