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# Applicability of Bolton's tooth size ratios in Mediterranean, Japanese and Japanese-Brazilian populations

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## Abstract

**Objective:** The aim of this study was to determine if Bolton's tooth size ratios can be applied to Mediterranean, Japanese and Japanese-Brazilian populations. **Materials and methods:** The sample comprised 90 pairs of dental casts of untreated individuals with normal occlusion, divided into 3 groups according to ethnical characteristics: White (30 Mediterranean descendant subjects, with a mean age of 13.64 years), Japanese (30 subjects with Japanese ancestry, with a mean age of 15.63 years) and Japanese-Brazilian (30 Japanese-Brazilian subjects, with a mean age of 13.96 years). A digital caliper was used to measure the maxillary and mandibular mesiodistal widths from first molar to first molar on each dental cast. The anterior and overall tooth size ratios were calculated. T test was applied for comparisons between Bolton standards and the ethnical groups for anterior and overall ratios. **Results:** Only the Japanese-Brazilian group showed significantly greater ratios than Bolton standards. **Conclusion:** It was concluded that Bolton's ratios are not applicable to the Japanese-Brazilian population. Therefore, it is suggested that Bolton's ratios may not be suitable for different populations.

**Keywords:** Dental occlusion. Ethnic groups. Orthodontics.

## Introduction

Tooth size proportion is an important factor in orthodontic diagnosis and treatment planning[1]. Appropriate tooth width proportion between maxillary and mandibular teeth is required to achieve ideal occlusal interdigitation, overjet and overbite at the end of orthodontic treatment[2]. When a discrepancy is not detected, it may take longer to finish treatment and result in compromised outcome1. Thus, it seems prudent for clinicians to include routinely a tooth size analysis during treatment planning[3].

Although different methods of measuring tooth size proportions have been developed[4,5], Bolton's tooth size ratio[2] is the most commonly accepted and recognized as an important diagnostic tool for detecting interarch tooth size discrepancies. Ideal

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anterior and overall ratios for proper harmony of maxillary and mandibular teeth were established with mean values of 77.2% (SD = 1.65%) and 91.3% (SD = 1.91%) respectively[2]. Despite its importance in the clinical setting to guide the orthodontist in cases with extreme tooth size discrepancies, Bolton's ratios have limitations, since the population and sex proportions of his sample were not specified, which implies potential selection bias[6].

There is evidence in the literature pointing towards ethnic differences in tooth size ratios[6-8]. It is reported that people with African ethnic backgrounds have larger teeth than do Japanese and Caucasians[9]. Because population differences in maxillary tooth size are not the same as the differences in mandibular tooth size, different interarch relationships might be expected[6].

Currently, the information regarding tooth size discrepancy prevalence among ethnicities is controversial. Although some studies report that Bolton's ratios can be applied for different populations[10,11], others claim the opposite[6-8,12,13]. Smith et al.[6] (2000) found significant differences in interarch ratios between Whites, Blacks and Hispanics. Uysal and Sari[12] (2005) concluded that Bolton's original data do not represent Turkish people. Endo et al.[7] (2007) detected a high prevalence rate of anterior tooth size discrepancy of more than 2SD above Bolton's mean and concluded that Bolton anterior ratio is not applicable to the Japanese population. Paredes et al.[8] (2011) noticed that anterior ratios for Peruvian and Spanish people are greater than Bolton's. Subbarao et al.[13] (2014) also found significant differences for the anterior and overall ratios compared to Bolton's ratios in an Indian population. These studies highlight the need for population-specific standards for clinical assessments of tooth size ratios.

Based on the controversy of the evidence available, studies are needed to assess the applicability of Bolton's ratios across different ethnicities. Therefore, the purposes of this study are to determine anterior and overall ratios in Mediterranean, Japanese and Japanese-Brazilian populations and to compare them with Bolton's standard ratios.

## Materials and Methods

### Sample selection

The sample comprised 90 pairs of dental casts of untreated Brazilian individuals, with normal occlusion and harmonious face, obtained from the files of the Orthodontic Department at Bauru Dental School, University of São Paulo, Bauru, Brazil. The sample was divided into 3 groups, according to ethnical characteristics. The White group consisted of 30 Mediterranean descendant subjects (15 male and 15 female), with a mean age of 13.64 years. The Japanese group consisted of 30 subjects with Japanese ancestry only (15 male and 15 female), with a mean age of 15.63 years. The Japanese-Brazilian group consisted of 30 Japanese-Brazilian subjects (Japanese blended with White Mediterranean subjects - 15 male and 15 female), with a mean age of 13.96 years.

The selection criteria were complete permanent dentition from first molar to first molar in both arches, Angle Class I molar relationship, with no crowding, no dental anomalies of number, size and shape, normal overbite and overjet relationships, absence of large restorations or caries that could affect the teeth's mesiodistal diameter, dental casts in good conditions and ethnicity verified by photographs and subjects' history obtained in surveys filled out by themselves or by their guardians.

### Data collection

The measurements were directly performed on the dental models, by one examiner (K. L. S.). A digital caliper (Mitutoyo Co, Kanagawa, Japan) accurate to 0.01 mm was used for measurements. The mesiodistal widths of each tooth from the maxillary and mandibular right first molar to the left first molar were measured at the largest distance between the contact points on the proximal surfaces. The caliper was positioned by the vestibular surface, parallel to the occlusal surface and perpendicular to the long axis of the crown. The anterior and overall Bolton ratios were calculated, according to the formulas:

(Sum mandibular "6"/Sum maxillary "6")*100 = anterior ratio (%)

(Sum mandibular "12"/Sum maxillary "12")*100 = overall ratio (%)

### Error Study

To evaluate intra examiner errors, the measurements were repeated 30 days after the first assessment in 30 pairs of randomly selected study casts. Random errors were estimated with Dahlberg's formula and systematic errors were evaluated with paired t tests.

### Statistical analysis

Since all variables presented normal distribution according to Kolmogorov-Smirnov tests, t test was applied to evaluate intersex differences and for comparisons between Bolton standards and the ethnical groups for anterior and overall tooth size ratios.

Statistical analyses were performed with Statistica software (Statistica for Windows 7.0 Copyright StatSoft, Inc. Tulsa, Okla, USA). Results were considered significant at $P < 0.05$

## Results

There were no significant systematic errors, and the random errors of the mesiodistal diameters of each tooth were within acceptable limits[14,15], ranging from 0.10 (canines) to 0.31 mm (molars).

There were no statistically significant intersex differences within each ethnicity for both anterior and overall ratios (Table 1).

Only the Japanese-Brazilian group showed significantly greater anterior and overall ratios than Bolton standards (Table 2).

For the anterior ratio, Japanese-Brazilians presented more subjects outside Bolton standards ±2SD, followed by White and Japanese subjects. For the overall ratio, Japanese-Brazilians presented more patients outside Bolton standards ±2SD, followed by Japanese subjects (Table 3). The White subjects were within the overall standards ±2SD.

**Table 1 -** Intersex differences for anterior and overall tooth size ratios (t tests).

| | White | | | | Japanese | | | | Japanese-Brazilian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anterior ratio | | Overall ratio | | Anterior ratio | | Overall ratio | | Anterior ratio | | Overall ratio | |
| | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Mean | 77.943 | 77.224 | 92.048 | 91.292 | 76.933 | 76.133 | 90.669 | 90.685 | 78.663 | 78.528 | 93.027 | 92.067 |
| SD | 2.930 | 2.186 | 1.857 | 1.627 | 1.641 | 1.844 | 1.637 | 2.045 | 2.861 | 2.132 | 1.877 | 1.646 |
| P | 0.453 | | 0.246 | | 0.220 | | 0.981 | | 0.885 | | 0.148 | |

**Table 2 -** Comparisons between Bolton standards and the ethnical groups for anterior and overall tooth size ratios (t test).

| | Bolton (n=55) | | White (n=30) | | | Japanese (n=30) | | | Japanese-Brazilian (n=30) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | P | Mean | SD | P | Mean | SD | P |
| Anterior Ratio | 77.2 | 1.65 | 77.584 | 2.566 | 0.410 | 76.533 | 1.763 | 0.084 | 78.596 | 2.480 | 0.003* |
| Overall Ratio | 91.3 | 1.91 | 91.670 | 1.759 | 0.383 | 90.677 | 1.820 | 0.150 | 92.547 | 1.802 | 0.004* |

* Statistically significant at $P < .05$

**Table 3 -** Number and percentage of subjects outside Bolton standards ± 2 SD.

| | Anterior ratio | | | | | | Overall ratio | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | < 2 SD | | > 2 SD | | Total | | < 2 SD | | > 2 SD | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| White | 6 | 20 | 2 | 6.67 | 4 | 13.33 | 0 | - | 0 | - | 0 | - |
| Japanese | 3 | 10 | 3 | 10 | 0 | - | 2 | 6.67 | 2 | 6.67 | 0 | - |
| Japanese-Brazilian | 9 | 30 | 1 | 3.33 | 8 | 26.67 | 3 | 10 | 0 | - | 3 | 10 |

## Discussion

Bolton's[2] (1962) sample consisted of 55 dental models with excellent occlusion, most of them orthodontically treated (44 cases). He did not specify the population and sex distribution of his sample. Our sample consisted of dental models of untreated subjects with optimal occlusion, and the ethnic groups should be as pure as possible. The difficulties to obtain a sample with those characteristics explain the rather small sample size of the present study.

It is generally agreed that there is no sex difference in tooth size ratios, as many studies report absence of sexual dimorphism in anterior and overall ratios[1,7,10,11,16-19]. Since we didn't find any statistically significant intersex difference in either anterior or overall ratios, and, also, Bolton2 (1962) did not specify the sex composition of the sample used in his study, we found it reasonable to combine male and female ratios to compare our tooth size ratios with his results.

We did not find significant differences for the anterior and overall ratios in Mediterranean nor in Japanese, indicating that Bolton standards can be used in these populations. Similarly, other studies did not report differences in both anterior and overall ratios comparing different populations with Bolton standards[10]. On the other hand, contrasting results were reported by Endo et al.[7] (2007), who found anterior and overall ratios from a Japanese population greater than those from Bolton's American population.

Although we did not find significant differences, the Japanese group in our sample presented smaller values for anterior and total ratios. A possible explanation for this tendency may be the high prevalence of shovel-shaped maxillary incisors in the Japanese population[20,21], in which the pronounced marginal ridges increase incisor thickness. Bolton[2] (1962) pointed out that the anterior ratio could be affected by tooth thickness. Rudolph et al.[22] (1998) stated that the prediction of the ideal intermaxillary ratio is more accurate when both tooth thickness and mesiodistal tooth width are considered. According to Halazonetis[23] (1996), each 0.2 mm change in tooth thickness represents 1% change in Bolton anterior ratio, i.e., a 1 mm change in incisal edge thickness may affect Bolton anterior ratio in up to 5%, which can represent almost 3 mm of tooth size discrepancy. Therefore, the ideal ratios may need adjustments, depending on the tooth thickness or the overjet that will remain at the end of treatment[23]. In order to obtain proper interdigitation and an ideal overjet and overbite relationship, the intermaxillary ratio must be smaller for dental arches with large labiolingual incisor thickness[22,23].

The Japanese-Brazilian group showed significantly greater anterior and overall ratios than Bolton standards. Other studies also reported significantly greater anterior ratio[8,7,13,24] and overall ratio[6,13,25] than Bolton standards for different populations.

Since the Japanese-Brazilian subjects represent a mixed race, it could be expected that they presented ratios between Mediterranean and Japanese. Curiously, the Japanese subjects showed smaller values, followed by Mediterranean and Japanese-Brazilians. Further studies should be undertaken to investigate this issue.

According to Bolton[2] (1962), a value greater than 1 SD from his means indicates the need for diagnostic consideration, but its clinical relevance is questionable. More recently, a clinically significant tooth size ratio discrepancy has been defined as 2 SD outside Bolton's original mean ratios[7,12]. Following the same rationale from other studies[7,12], we also defined ratios outside of 2 SD from Bolton's means as values indicating a clinically significant

discrepancy, as approximately 95% of Bolton's cases were within this range. We observed a higher prevalence of discrepancy in the anterior segment of the dental arches. Significant tooth size discrepancies for anterior ratio were found in 10% of the Japanese, 20% of the Mediterranean and 30% of the Japanese-Brazilian. No discrepancy was found in overall ratio in Mediterranean, while it varied from 6.67% in Japanese to 10% in Japanese-Brazilian. These data corroborate with results reported in other studies, in which discrepancies of 21.3%[12], 28.18%[1] and 30.6%[3] for anterior ratio, and 13.5%[3] and 13.64%[1] for overall ratio have been reported. Most of the discrepancy found in this study was characterized by mandibular excess, confirming the results presented by Freeman et al.[3] (1996) and Endo et al.[7] (2007).

According to the results obtained in this study in comparison to others, we can speculate that the values of tooth size ratios can vary not only between sex or populations. Surprisingly, the same population can show contrasting results. Therefore, generalized use of Bolton's ratios is questionable and may not be suitable for different populations.

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