ORIGINAL RESEARCH

Frequency of Bolton Tooth-size Discrepancy among Saudi Orthodontic Subjects and Relevance in Concordance with Gender Predilection

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ABSTRACT

Aims: The aims of this study were to determine the prevalence of Bolton intermaxillary tooth-size discrepancy among Saudi orthodontic patients and to evaluate gender differences.

Materials and methods: Pretreatment study models of 98 Saudi orthodontic patients (45 men and 53 women) were included in this study. The mesiodistal width from 1st molar to the opposite 1st was measured by a digital caliper, and Bolton anterior ratio (BAR) and Bolton overall ratio (BOR) were calculated. The independent samples t-student test was used to compare the values of BAR and BOR between men and women. The Chi-square test was used to test the gender differences in patients having Bolton tooth-size ratio away from 2 SD of Bolton mean value.

Results: Significant differences were not found between men and women in BAR and BOR. The frequency of intermaxillary tooth-size discrepancy was 21.6% and 17.3% for anterior and overall ratio, respectively. Significant differences were found between men and women in the anterior and overall intermaxillary tooth-size discrepancy.

Conclusion: Male orthodontic patients possess significantly more anterior and overall intermaxillary tooth-size discrepancies than female patients. Furthermore, the prevalence of Bolton tooth-size discrepancy in Saudi orthodontic patients is quite large enough to lead clinicians to be aware of it and proceed Bolton index in their quotidian orthodontic diagnosis.

Clinical significance: The failure to diagnose intermaxillary tooth-size discrepancies prevents obtaining optimal occlusal relationship and increases the duration of the orthodontic therapy. Clinicians must consider Bolton tooth-size analysis as a primordial tool in their quotidian orthodontic diagnosis process and treatment planning so that they can avoid embarrassing situations at the end of the treatment.

Keywords: Bolton analysis, Ideal occlusion, Orthodontic treatment, Tooth-size discrepancy.

How to cite this article: Maamar E, Bukhari SAA, Hakami R, Abdulfatah BA. Frequency of Bolton Tooth-size Discrepancy among Saudi Orthodontic Subjects and Relevance in Concordance with Gender Predilection. World J Dent 2019;10(1):23-28.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Orthodontic treatment in pursuit of achieving an ideal and optimal occlusion has always looked for the six keys of occlusion as laid down by Andrews. Bolton in 1958 suggested the 7th key to ideal occlusion for the discrepancy of maxillary and mandibular tooth size as a prerequisite to obtaining a proper interdigitation.[1] Nevertheless to mention here that the stability and durability of orthodontic treatment outcomes depend on good occlusal interdigitation and optimal overjet and overbite obtained at the close of the treatment. It has been reported that the failure to diagnose tooth-size discrepancies prevents obtaining optimal occlusal relationship and increases the duration of the orthodontic therapy.[2] The substantial impact of tooth-size discrepancies on the final orthodontic outcome has been reported in orthodontic literature over a period of time. Black[3] in 1902 was the first to suggest a table of tooth-size mean which is still used at the present date. In addition, the tooth-size measurements of Wheeler[4] are frequently used as well. In 1944 Ballard evaluated the tooth size asymmetry by measuring 500 set of models.[5] He found that 90% of his sample demonstrated 0.25 mm or more discrepancy in mesiodistal width of one or more pairs of teeth from the opposite sides of the arch. He concluded that "asymmetry is the rule, not the exception" and rational interproximal reduction of enamel is sometimes necessary to obtain a proper teeth interdigitation. Neff developed an anterior coefficient derived from his study comprising the measurement of mesiodistal width of upper and lower teeth of 200 subjects.[6] This anterior coefficient was suggested to compare the width of the anterior teeth of both arches. Lundström studied the variation of intermaxillary tooth width ratio and its impact on tooth alignment and occlusion. He concluded that a large biologic dispersion of tooth width ratio was great enough to impact the final tooth position, teeth alignment, and anterior overjet and overbite relationships.[7]

Bolton's[1] intermaxillary tooth-size ratio is widely used as an indispensable element of orthodontic diagnosis

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since its introduction.[8] In his study, Bolton selected 55 subjects with excellent occlusion, most of which had been treated with a non-extraction orthodontic approach. Calipers with sharp ends were used in the mesiodistal width measurements of the maxillary and mandibular teeth (from first molar to first molar). The sum of 12 maxillary teeth was compared to the 12 mandibular teeth. The derived ratio between the two gave the relationship of mandibular arch length to maxillary arch length in percentage.

$$\frac{\text{Sum mandibular "12"}}{\text{Sum maxillary "12"}} \times 100 = \text{Overall ratio}$$

Likewise, the relationship of mandibular six anterior teeth (canine to canine) to maxillary 6 anterior teeth is analyzed by the anterior ratio.

$$\frac{\text{Sum mandibular "6"}}{\text{Sum maxillary "6"}} \times 100 = \text{Anterior ratio}$$

He stated that an anterior ratio of 77.2 and an overall ratio of 91.3 were necessary for optimal coordination of maxillary and mandibular teeth.

It has been reported that the tooth-size ratios are race- and sex-specific.[9,10] Smith et al. conducted a study, in which they evaluated the applicability of Bolton's ratio in different populations among different genders, and concluded that the Bolton's ratios were applicable only to Caucasian women and should not be indiscriminately applied to Caucasian men, Blacks, or Hispanics and that the overall ratio was significantly larger in men than in women.[11]

The frequency of tooth-size discrepancy has been established by many investigators for different ethnical groups. Crosby and Alexander[12] conducted a study on the occurrence of tooth-size discrepancies among patients with different malocclusions. They found no significant difference in the incidence of intermaxillary tooth size discrepancies in different malocclusion groups. Freeman et al.[13] conducted a study on the percentage of Bolton discrepancies among orthodontic patients at US military orthodontic programs. Nie and Lin[14] conducted a study among the Chinese population to compare Bolton tooth-size discrepancies among different malocclusion groups for both sexes. They found a significant difference in tooth-size ratios between the groups in which the class III group had a higher mean value than class I and class II (CLIII > CLI > CLII). However, sexual dimorphism for these ratios did not exist in each group. Uysal et al.[15] evaluated difference in the incidence of tooth-size discrepancies for both the anterior and overall ratios when comparing with different malocclusion groups.

Several pieces of evidence with regards to the intermaxillary tooth-size discrepancy led to a wide agreement that ethnicity and sex specificity are important factors in the occurrence of Bolton tooth-size discrepancy. Most investigations on the frequency of Bolton tooth-size discrepancy focused on the ethnical variability.[16-18]

AIM

The objective of the present study was to evaluate the relationship between gender and occurrence of the clinically significant Bolton tooth-size discrepancy outside 2 SD of Bolton's means among Saudi orthodontic subjects who presented at the orthodontic clinics of College of Dentistry, Jazan University seeking for orthodontic treatment.

MATERIALS AND METHODS

The present study is a retrospective study wherein from a pool of archival records of 400 subjects were selected who had presented for the orthodontic treatment or evaluation in the clinics of the Department of Orthodontics, Jazan University.

Ethical Consideration

The ethical clearance for the study was obtained by submitting the study proposal to the institutional board of research, College of Dentistry, Jazan which comprises both the ethical committee as well as the review board. This present study was conducted in full accordance with the World Medical Association Declaration of Helsinki. No informed consent was taken from the subjects involved in this study. Only after taking the approval from the said board for conducting the study, the records of the patients who had attended the orthodontic department either for diagnosis or treatment were accessed. The inclusion of the records from the archival pool of patients was selected only after keeping the identity of the records anonymous from all the participants involved in the research.

Sample

The sample of the present study consisted of 98 pretreatment orthodontic casts (45 male and 53 female) selected based on the inclusion and exclusion criteria out of the 400 casts already chosen for the study from the orthodontic clinic in the College of Dentistry, Jazan University.

The inclusion criteria for the selection of the casts were:
- Belonging to Saudi with Saudi grandparents
- All permanent teeth (except wisdom teeth) erupted
- No previous orthodontic treatment.

The exclusion criteria included the following:
- Interproximal caries or restoration
- Any anomaly of size or shape
- Congenital missing or supernumerary teeth
- Minimal tooth wear.

Before the analysis, the selected subjects` casts were kept anonymous from all the participants involved in the study and all the data related to the subjects were deidentified to remove the bias that would occur as a result of this thereof.

Measurement Method

A digital caliper was used to measure the mesiodistal width of teeth to the nearest of 0.01 mm. The width of each tooth was measured according to the method of Moorrees et al.[19] One tip of the caliper was placed on the mesial contact point and the other tip on the distal contact point at the greatest interproximal distance. The mesiodistal widths of the 12 maxillary teeth (first molar to the first molar) were summed up and compared with the sum of the 12 mandibular teeth. The Bolton anterior ratio (canine to canine) and Bolton overall ratio were calculated as formulated by Bolton:

$$\text{Bolton anterio ratio (BAR)} \frac{\text{Sum mandibular "6"} \times 100}{\text{Sum maxillary "6"}}$$

$$\text{Bolton overall ratio (BAR)} \frac{\text{Sum mandibular "12"} \times 100}{\text{Sum maxillary "12"}}$$

Statistical Analysis

Recorded values of mesiodistal width of upper and lower teeth were entered into excel sheet. Statistical analyses were performed using SPSS (version 21). The independent samples t-student test was used to compare the values of BAR and BOR between men and women. The prevalence rates of anterior and overall tooth size discrepancies outside 2 SD from the Bolton means were calculated. The Chi-square test was used to test the gender differences in patients having an intermaxillary tooth-size discrepancy. Significance differences were set at 0.05 ($p < 0.05$).

Error of Measurement

Randomly selected 20 casts were remeasured after 4 weeks of the first measurement by the same examiner. Paired samples t-test was used to test the significant differences between the first and second measurements ($p > 0.05$). No statistically significant differences were found between the two sets of measurements ($p = 0.97$).

RESULTS

The mean and standard deviation of Bolton overall (BOR) and anterior ratios (BAR) for male, female and total orthodontic patients are shown in Table 1. The means of BOR were 93.1 ± 3.4 and 91.4 ± 2.6 for male and female patients respectively. The means of BAR were 78.8 ± 3.1 and 78.0 ± 3.04 for male and female subjects respectively. For the combined subjects the mean values were 92.2 ± 3.4 and 78.0 ± 3.1 for BOR and BAR, respectively. The differences between male and female patients were found to be non-significant in both BOR and BAR. The mean value of BOR and BAR of combined patients were 92.2 ± 3.4 and 78.0 ± 3.1, respectively.

Table 2 compares the means and standard deviations in BAR and BOR of tooth-size discrepancy between the present sample and Bolton's study.

The distribution of BAR discrepancy according to Bolton's anterior mean value with 2 SD is shown in Graph 1. In the present study, the frequency of BAR discrepancy outside 2 SD of Bolton mean value in Saudi orthodontic patients was found in 21 patients (21.4% of total patients). The anterior tooth-size discrepancy was found likely to be maxillary excess in 3 patient (3.1% of total sample) and likely to be mandibular in 18 patients (18.4% of total sample)

Graph 2 demonstrates the frequency of BOR discrepancy according to Bolton's mean value with 2 SD. Eighteen patients (18.4 % of total patients) recorded overall Bolton ratio discrepancies which fell outside of 2 SD from Bolton overall mean value. While overall tooth-size discrepancy in Saudi orthodontic patients was found likely to be a maxillary excess in 1.02% of total patients, 17.3% of total patients were likely to have an excess in the mandibular arch.

In the present study, the male orthodontic patients recorded more anterior tooth-size discrepancy away from 2 SD of Bolton mean value than female patients (15.3% and 6.1%, respectively) as shown in Table 3. The Chi-square test revealed significant differences in the clinical anterior tooth-size discrepancy between men and women ($p < 0.05$). Moreover, the male orthodontic patients recorded highly significant values more than female patients in overall discrepancy away of 2 SD of Bolton mean value (14.3% and 3.1% of combined patients for male and male patients, respectively).

Table 1: The mean and standard deviation (SD) for the anterior and overall tooth size discrepancy for male and female subjects

|	Male (45)		Female (53)			Total sample (98)	
	Mean	SD	Mean	SD	p value	Mean	SD
Overall ratio	93.1	3.4	91.4	2.6	0.07 NS	92.2	3.4
Anterior ratio	78.8	3.1	77.3	3.04	0.09 NS	78.0	3.1

NS: Not significant (p <0.05).

Table 2: Mean and standard deviation (SD) in anterior and overall tooth-size discrepancy for the present sample and Bolton's study

	Anterior ratio			Overall ratio		
	Mean	*SD*	*Range*	*Mean*	*SD*	*Range*
Bolton (1958) (n = 55)	77.2	1.6	74.5–80.4	91.3	1.9	87.5–95.8
Present study (n = 98)	78.01	3.6	66.2–91.1	92.2	3.6	72.7–101.1
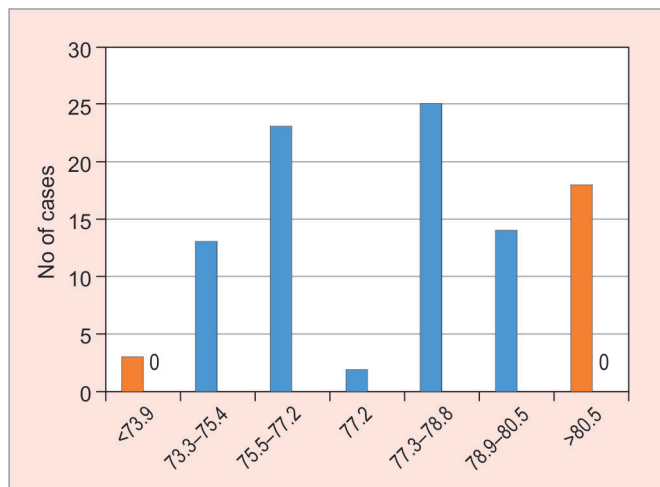
Graph 1: Distribution of 98 Saudi orthodontic subjects' anterior tooth-size ratios' according to Bolton's mean and 2 SD
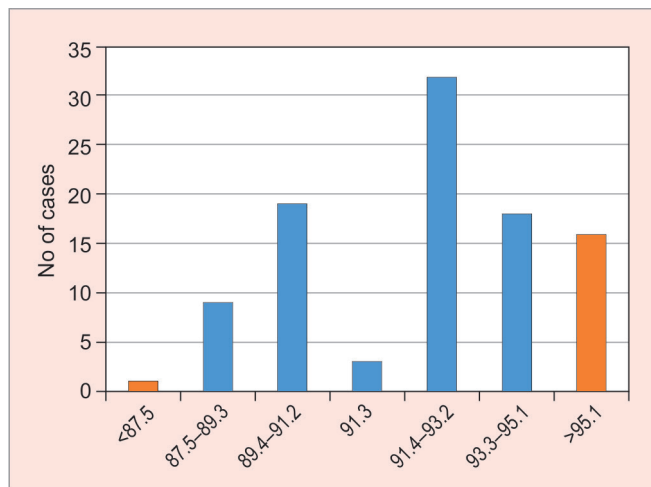
Graph 2: Distribution of 98 Saudi orthodontic subjects' overall tooth-size ratios' according to Bolton's mean and 2 SD

Table 3: Number and percentage of anterior and overall ratio outside 2 SD in male and female subjects

	Male (44)		Female (53)		
	Frequency	*Percentage (%)*	*Frequency*	*Percentage (%)*	*p value*
Anterior ratio outside 2 SD	15	15.3	6	6.1	0.012*
Overall ratio outside 2 SD	14	14.3	3	3.1	0.001*

*Significant ($p < 0.05$)

DISCUSSION

The findings of our study showed remarkable significant differences in the prevalence that were considered to be of clinical significance in the anterior and overall Bolton tooth-size discrepancy between men and women among Saudi orthodontic patients. Although, however, significant sex differences in overall ratio tooth-size have been reported Aldress et al.[20] among Saudi orthodontic patients, the sex difference in anterior tooth-size discrepancy was found not significant. These findings of sex dysmorphism in clinically significant anterior and overall tooth discrepancy need to be confirmed by more investigations on other ethnical populations.

In the present study, although, the mean of anterior and overall ratio (78.0 ± 3.6 and 2.2 ± 3.6, respectively) of tooth size discrepancy was found greater than those of Bolton sample (91 ± 31.91 and 77.2 ± 1.56 respectively), these differences between the mean value of Saudi sample and those of Bolton`s mean value were not found significant. The standard deviations are highly larger than Bolton`s standard deviation. This wide standard deviation can be explained by the fact that the subjects of the present study are orthodontic patients and having different malocclusion while Bolton's sample was a normal class I and clinically treated cases. Our findings were consistent with previous studies.[12-18] However, while the anterior ratio of Japanese orthodontic patients demonstrated a significant difference from Bolton's, the overall ratio demonstrated no significant difference.[2]

Although, Bolton did not specify the sex of his original sample, his most orthodontic patients in 1950s were white women.[11] Thus, Bolton did not discuss the gender difference in his original study. Several studies reported no significant differences between male and female orthodontic patients in the anterior and overall ratio which agree with the findings of our study. However, other studies reported a significant difference between men and women in anterior ratio.[11,18,21]

In the present study, the intermaxillary tooth-size discrepancy was considered clinically significant when the ratio fell outside 2 SD from Bolton's mean value. This definition is consistent with most previous studies,[16,18,21,22] although, Bolton in 1962 considered a ratio value more than 1 SD as a possible treatment need.[2] Nearly 21.6% of Saudi orthodontic patients recorded BAR away from 2 SD of Bolton mean value. This finding is similar to the percentage found in the other populations by Paredes et al. (21%),[10] Crosby and Alexander (22.9%),[12] Uysal et al.

(21.3%),[15] Al-Omari et al. (23.7),[22] Bernabe et al. (20.5%)[23] and Endo et al. (21.6).[21] However the findings of our study differed and were less in values as compared to studies concluded by Freeman et al. (30.6%)[13] and Santoro et al. (28%).[17]

Likewise, 17.3% of Saudi orthodontic patients demonstrated clinically significant Bolton overall discrepancy falling in concordance with those of Uysal et al. (18%),[18] Aljunaid et al. (14.2%) for Yemenis,[24] and Freeman et al. (13.4%) for Americans.[13] Lesser percentages for the overall ratio tooth-size discrepancy, however, were found by Al-Omari et al. (9.5%) for Jordanians,[22] Endo et al. (7.6%) for Japanese[21] and Bernabe et al. (5%) for Peruvians.[23]

The large percentage, reported by this present study, of Saudi orthodontic patients present with significant tooth-size discrepancy is quite enough to be warranted to orthodontists leading them to implement the Bolton index in the full orthodontic workup of their patients. The orthodontic diagnosis supported with Bolton's ratio usually results in a comprehensive orthodontic therapy that may require prosthetic and restorative procedures or even interproximal stripping in order to establish a stable and excellent occlusal relationship.[11] The tooth-size discrepancy might be caused by maxillary or mandibular tooth excess. In this study, the mandibular excess tooth-size discrepancies were found higher than maxillary excess in both anterior and overall ratio. In anterior ratio, 18.4% of orthodontic patients were found more likely to have mandibular excess while only 3.1% for maxillary excess patients. Likewise, 17.3% of orthodontic patients were found more likely to have mandibular excess in patients with overall Bolton discrepancies and over three folds more than patients with maxillary excess (1.02%).

In the present study, significant differences between men and women were found in the anterior and overall tooth-size discrepancy. While 15 male orthodontic patients (15.3% of total patients) have clinically significant BAR toot-size discrepancy, only 6 of female patients (6.1% of total patients) recorded BAR tooth-size discrepancy, Likewise, in overall Bolton's discrepancy men recorded clinically significant BOR discrepancy (14.3% of total patients) more than 4 times that of the women (3.1% of total patients). Nevertheless, the results of the present study should not be a deterrent to the orthodontists when formulating the treatment plan for the female population, and it is advised to conduct more researches in the respective populations to confirm the findings of the Bolton's discrepancy with 2 SD.

CONCLUSION

The findings of the present study suggest that male orthodontic patients are likely to possess an intermaxillary tooth-size discrepancy more than female patients. Moreover, the prevalence of intermaxillary tooth-size discrepancy among the Saudi sample seems to be significant enough in a large number for both genders of patients seeking orthodontic therapy. Clinicians should be aware of this discrepancy that may influence orthodontic treatment goals and outcomes substantially. Thus, Bolton tooth-size index must be a primordial tool in quotidian orthodontic diagnosis process and treatment planning.

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