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Association between Tooth Size Discrepancies and Angle Malocclusions in a Tunisian Sample

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Abstract		Original Research Article

Objective: The objective of this study was to investigate the frequency and to compare the overall and anterior ratios of tooth size discrepancies in all Angle malocclusions groups. ***Materials and methods:*** The mesio-distal tooth width and arch width were measured on a total of 120 orthodontic 3D models of Tunisian patients aged between 18–37 years of different occlusal relationships (Class I, Class II division 1 Class II division 2 and Class III malocclusions). The overall and anterior ratios between the maxillary and mandibular teeth were evaluated using Bolton's method. The following statistical tests were applied: independent t-test, and one-way ANOVA. ***Results***: Women presented smaller teeth than men, which mainly concern the first molar in the maxilla, the canine, the second premolar and the first molar in the mandible. The anterior ratio was 78.59% ± 2.47, with 78.93% ± 2.41 for men and 78.26% ± 2.54 for women and the overall ratio was 91.69% ± 1.41 with 92.21% ± 1.30 for men and 91.16% ± 2.37 for women. There was no relationship between anterior and overall ratio and gender or malocclusion groups. ***Conclusion***: This work showed the presence of sexual dimorphism concerning tooth size. Our comparison of the TSD results with those noted by Bolton, showed anterior and overall ratios that are slightly higher than his standard values. Therefore, the original Bolton's values should be used conservatively in Tunisian population. No differences in the overall and anterior ratios of tooth size discrepancies were found among Angle malocclusion groups and gender.
Keywords: Tooth size; Bolton ratio; Tooth size discrepancy; malocclusion.

INTRODUCTION

A proper balance should exist between the mesiodistal tooth size of the maxillary and mandibular arches to ensure proper intercuspdation, overbite, and overjet at the end of orthodontic treatment. The purpose of the final phase of orthodontic treatment is to make the occlusion perfect, both functionally and aesthetically [1]. In many cases, the finishing phase is difficult and time consuming [2]. Lots of these difficulties are related to the tooth size discrepancies between upper and lower dentition [2, 3]. After the introduction of the "six essential keys of normal occlusion" by Andrews in 1972 [4], further studies [5] put importance on the "seventh key" which was the "tooth size".

Furthermore, difference in tooth size have been associated with different ethnic backgrounds and also with different malocclusions [6, 7], influenced by genetic [8, 9] and environmental factors [10] and various studies have investigated ethnic and sex differences in the intermaxillary tooth ratios. Bolton's ratio is one of the most commonly used methods to determine inter-arch tooth size discrepancy in orthodontic patients and has been widely used in scientific studies since its publication [11, 12]. However, due to the selection bias in Bolton's study (subjects with an excellent occlusion were selected for his study, while population and gender characteristics of the study sample were unspecified), Bolton's ratio may differ in the subjects with malocclusions and in different population groups [13-16].

Considering that there are very few studies that focused on the association between Bolton discrepancy and Angle malocclusions, and the available literature is inconsistent. Therefore, the purpose of this study was to compare the overall and anterior Bolton ratios among different malocclusion groups using a sample from the Tunisian population.

MATERIALS AND METHODS

A total of 120 sets of 3D models were obtained from patients (age range 18–37 years), who consulted the Dentofacial Othopedics Department of the Monastir Dental Clinic, including the different malocclusions groups (Class I, Class II division 1, Class II division 2, and Class III malocclusions). The distribution of subjects according to sex and malocclusion group is shown in Table-1.

Table-1: Distribution of Subjects According to Sex and Malocclusion Group

Gender	Angle class				Total
	Class I	Class II div1	Class II div2	Class III	
Number of males	21	10	9	20	60
Number of females	19	11	10	20	60
Total	40	21	19	40	120

The inclusion criteria for the subjects were as follow:
1. Complete permanent dentition with no caries, proximal restorations, attrition, or dental anomalies.
2. All teeth fully erupted to the occlusal plan.
3. No previous or ongoing orthodontic treatment.
4. No transverse discrepancies such as cross bite or scissors bite.
5. Tunisian origin

The mesio-distal tooth width from first molar to first molar was obtained on the orthodontic 3D models by measuring the greatest distance between the contact points on proximal surfaces using the software Inlab SW version 19.

These measurements were performed by the same operator and were compared to measurements made with a digital caliper with an accuracy of 0.01 mm on 15 randomly selected upper and lower casts; any difference greater than 0.5 mm was considered clinically significant [16]. The result of this comparison showed a negligible difference, of the order of 0.02 to 0.2 mm, which confirms the reliability of the software used in this study.

The method proposed by Bolton [10] was adopted for calculation of tooth size discrepancy:

Anterior ratio (AR) = [(Sum of mesio-distal width of mandibular six anterior teeth)/ (Sum of mesio-distal width of maxillary six anterior teeth)] × 100%

Overall ratio (OR) = [(Sum of mesiodistal width of mandibular 12 teeth)/ (Sum of mesiodistal width of maxillary 12 teeth)] × 100%

STATISTICAL ANALYSIS

The statistical analysis was performed using IBM SPSS version 23.0 software and the significance level was set at $p < 0.05$ (5%). The t-test of independent samples was used to compare mesiodistal tooth width and TSD between men and women and the ANOVA test was used to compare the overall and ratio between the different groups of malocclusions.

RESULTS
Female to Male Comparisons
Tooth Size

The comparison of the tooth size between men and women showed the presence of sexual dimorphism.

In the maxilla, the first molar was significantly wider in men ($p<0.001$). In the mandible, the canine ($p<0.01$), second premolar ($p<0.001$) and first molar ($p<0.001$) were significantly less wide in women (Table-2).

Table-2: Permanent tooth widths in Tunisian adults

Tooth	Men		Women		Total		p
	Mean	SD	Mean	SD	Mean	SD	
Maxillary							
I1	8.74	0.66	8.70	0,49	8.72	0.51	0.18
I2	6.98	0.50	6.90	0,43	6.94	0.47	0.25
C	7.82	0.35	7.70	0,33	7.76	0.34	0.16
P1	7.05	0.22	6.95	0,31	7	0.27	0.33
P2	6.87	0.28	6.78	0,25	6.82	0.24	0.09
M	10.42	0.43	10.04	0,50	10.23	0.44	0.0007***
Mandibular							
I1	5.52	0.44	5.45	0,41	5.48	0.42	0.08
I2	6.05	0.44	6.03	0,40	6.04	0.42	0.07
C	7.01	0.46	6.74	0,38	6.87	0.42	0.004**
P1	7.25	0.35	7.07	0,43	7.16	0.37	0.06
P2	7.42	0.42	7.13	0,42	7.27	0.35	0.0009***
M	11.19	0.59	10.78	0,57	10.98	0.58	0.0002***

I1, Central incisor; I2, lateral incisor; C, canine; P1, first premolar; P2, second premolar; M, first molar; SD, Standard deviation; * p < 0,05; ** p < 0,01; *** p < 0,001.

Tooth size discrepancies (TSD)

The anterior and overall ratios, according to the formulas published by Bolton were calculated and the resulting data were pooled in Table-3.

Our results showed that the anterior ratio was 78.59% ± 2.47, with 78.93% ± 2.41 for men and 78.26% ± 2.54 for women. The overall ratio was 91.69% ± 1.41 with 92.21% ± 1.30 for men and 91.16% ± 2.37 for women.

The t-test of the independent samples, used to compare the TSD between men and women, showed that this difference is not significant.

Table-3: Mean Ratios of Bolton Anterior and Overall Analysis as a Function of Sex

Gender		Number	Mean (%)	SD	p
Men	AR	60	78.93	1.41	0.15
	OR	60	92.21	1.30	0.09
Women	AR	60	78.26	1.54	0.25
	OR	60	91.16	1.37	0.08
Total	AR	120	78.59	1.47	
	OR	120	91.69	1.41	

AR: Anterior ratio; OR: Overall Ratio; SD: Standard deviation

Comparisons between the different malocclusion groups

The results obtained from the comparison of the overall and ratio between the different groups of malocclusions, using the ANOVA test, are summarized in Table-4. The descriptive analyses showed that the means were significantly similar and the difference obtained is not significant.

Table-4: Mean Ratios of Bolton Anterior and Overall Analysis as a Function of Angle Class

Angle Class/Bolton Ratio		Number	Mean (%)	SD	p
Class I	AR	40	78.06	1.57	0.08
	OR	40	91.87	1.61	0.14
Class II div 1	AR	21	78.76	1.23	0.16
	OR	21	90.28	1.23	0.28
Class II div 2	AR	19	78.54	1.55	0.33
	OR	19	90.62	1.71	0.89
Class III	AR	40	79.07	1.47	0.25
	OR	40	92.74	1.19	0.09
Total	AR	120	78.59	1.47	
	OR	120	91.69	1.41	

AR: Anterior ratio; OR: Overall Ratio; SD: Standard deviation;

DISCUSSION

Given that tooth size discrepancies may be influenced by malocclusion type, ethnicity and sex, the mesio-distal tooth width and the TSD was compared in relation to the different types of malocclusions of Class I, Class II division 1, Class II division 2 and Class III and according to the gender of 120 patients who consulted the Monastir Dentofacial Orthopedics Department.

Although diagnostic measurements have traditionally been based on plaster dental casts, with the advancement of 3D digital imaging technology, e-models are a valid alternative [17] Moreover, digital measurement is more rapid and less variable than the manual method.

The size of the teeth of the Tunisian population remains comparable to that of the teeth of individuals from Morocco and Saudi Arabia. However, this size remains smaller than those measured on melanoderms and relatively larger than those noted on Caucasians.

Studies of Hispanic populations, in particular, have shown that there is a significant difference in tooth size compared to Caucasians, but it is similar to that found in African-Americans.

According to Lavelle [18], the average mesio-distal crown diameter is larger in melanoderms than in Caucasians and Mongoloids are intermediate.

These variations are attributed to environmental, genetic, dietary and ethnic factors [19, 20, 21].

Similarly, we found that there is a significant difference in tooth size between men and women, shown in this study, which confirms the presence of sexual dimorphism. Thus, we observed that men have teeth larger than the opposite sex, which mainly

concern the first molar in the maxilla, and the canine, second premolar and first molar in the mandible. This is consistent with the results obtained in other studies in different populations [18, 22]. A Chinese study [23] found that females had statistically significant ($p < 0.05$) smaller teeth than males with the exception of the upper left and right lateral incisors, lower left lateral incisor, and lower left and right central incisors.

Bishara [24] found that canines and molars were significantly larger in boys than in girls, and he found no significant differences between incisors in three different populations (Mexico, Egypt and Iowa).

Several studies [9] have suggested that this sexual dimorphism is mainly related to Y-chromosome stimulation of growth [25, 26], while other researchers have suggested that hormonal influences during tooth development are also important.

In our study, the result of the measurement of the Bolton ratio, as a function of sex, showed that the AR was 78.59% ± 1.47, with 78.93% ± 1.41 for men and 78.26% ± 1.54 for women and the OR having an average of 91.69% ± 1.41, with 92.21% ± 1.30 for men and 91.16% ± 1.37 for women, these differences remain insignificant. This is in agreement with majority of previously reported findings [27-30], but contrasting findings have been reported by other studies [20, 31].

Our comparison of the TSD results with those noted by Bolton, showed an AR and OR that were slightly higher than his standard values (77.2% ± 1.65 for RA and 91.3% ± 1.91 for RG). This difference was to be expected since his standards are not applicable to all individuals. This inconsistency would be linked to criticism of this ratio, since, first of all, estimates of Bolton's ratio were underestimated because his sample was derived from patients with a perfect Class I occlusion. Similarly, the population and sex composition of Bolton's sample was not specified, which constitutes a potential selection bias.

Smith *et al.,* [20] mentioned that the parameters considered normal for Bolton's ratio cannot be applied only to white women and that there are significant differences in anterior and overall ratio between Whites, Blacks and Hispanics.

A review of the literature by Othman and Harradine [32] stated that Bolton's ratio is probably not a good indicator of the prevalence and diagnosis of the tooth size discrepancy and cannot be applicable to all populations. Therefore, it can be concluded that the Bolton index differs from one population to another, and even within the same population.

In this study, the comparison of the Bolton ratio according to the different malocclusions did not reveal any significant difference, which is in agreement with other studies carried out on other ethnic groups: studies by Crosby and Alexander [6] on a sample of 109 patients divided into four malocclusion groups (class I, class II division 1, class II division 2 and surgical class II), not including Angle's class III subject, did not show a statistically significant difference in the incidence of TSD between these four occlusion categories. Similarly, studies by Uysal *et al.,* [33] in 2005 on 150 patients with class I and 560 patients with the other malocclusion +groups (class I, class II division 1, class II division 2 and Angle class III) did not show statistically significant differences between the different classes of malocclusion. Similar findings have been reported from Japanese [34] and Moroccan [35] studies conducted in 2008 and 2014, respectively, stating that the TSD is not related to dental class. Akyalcin *et al.,* [36] found that in a skeletally similar sample of 152 subjects, no statistically significant differences were determined for the Bolton anterior and overall tooth size prevalence and means among the Angle Class I, II, and III groups and sex also was not discriminating.

However, several studies have affirmed the presence of a correlation between TSD and malocclusions. Lavelle showed that Bolton's ratios will be greater in class III subjects than in other occlusion classes, which is in agreement with the work of Nie and Lin [29].

Studies carried out on different populations in Brazil Araujo and Souki [2], Turkey Oktay [37], Ireland O'Mahony [38] and Poland and Croatia Wedrychowska-Szulc B [39] have revealed a relationship between the TSD and the incidence of malocclusion.

These observations suggest that there is a divergence of opinion among the authors regarding the incidence of TSD in malocclusions among different ethnic groups and thus remains a controversial issue that may be the source of future research in this subject.

CONCLUSION
- This work showed the presence of sexual dimorphism concerning tooth size. In fact, women presented smaller teeth than men, which mainly concern the first molar in the maxilla, the canine, the second premolar and the first molar in the mandible. On the other hand, this difference is not systematic and does not interest all teeth.
- Our comparison of the TSD results with those noted by Bolton, showed anterior and overall ratios that are slightly higher than his standard values. Therefore, the original Bolton's values should be used conservatively in Tunisian population.
- No differences in the overall and anterior ratios of tooth size discrepancies were found among Angle malocclusion groups and gender.

Conflict of Interest statement: All authors declare that we have no conflict of interest of this work.

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