Bolton tooth size ratio among Sudanese Population sample: A preliminary study

Ala'a Hayder Abdalla Hashim, AL-Hadi Mohi Eldin and Hayder Abdalla Hashim[1]

ABSTRACT

Background: The study of the mesiodistal size, the morphology of teeth and dental arch may play an important role in clinical dentistry, as well as other sciences such as Forensic Dentistry and Anthropology.

Aims: The aims of the present study were to establish tooth-size ratio in Sudanese sample with Class I normal occlusion, to compare the tooth-size ratio between the present study and Bolton's study and between genders.

Materials and Methods: The sample consisted of dental casts of 60 subjects (30 males and 30 females). Bolton formula was used to compute the overall and anterior ratio. The correlation coefficient between the anterior ratio and overall ratio was tested, and Student's *t*-test was used to compare tooth-size ratios between males and females, and between the present study and Bolton's result.

Results: The results of the overall and anterior ratio was relatively similar to the mean values reported by Bolton, and there were no statistically significant differences between the mean values of the anterior ratio and the overall ratio between males and females. The correlation coefficient was (r = 0.79).

Conclusions: The result obtained was similar to the Caucasian race. However, the reality indicates that the Sudanese population consisted of different racial groups; therefore, the firm conclusion is difficult to draw. Since this sample is not representative for the Sudanese population, hence, a further study with a large sample collected from the different parts of the Sudan is required.

Key words: Anterior ratio, Bolton ratio, overall ratio, Sudanese population, tooth-size

INTRODUCTION AND REVIEW OF LITERATURE

Teeth are the hardest tissues in the body, composed of two types, primary and permanent dentition, representing one of the important parts in the body, mastering the beauty of the face (esthetic), the function of mastication (digestion), and speech (phonation). They are arranged in harmony with each other and with other structures in the face and the mouth including muscles of mastication, the tongue and the bone of maxilla and mandible. However, in orthodontic, most of the patient complaints are crowding and spacing, and that are representing a big esthetic and functional problem.[1]

In the past, investigators have used "contact method" in measuring tooth-size. These measurements were carried out by using either a pair of dividers with millimeter ruler,[2-5] or sliding caliper with a vernier scale.[6,7] Furthermore, "noncontact methods" were used. These methods include prints of the

Department of Orthodontic, University of Medical Sciences and Technology, Dental College, Khartoum, Sudan, [1]Orthodontic Section, Hamad Medical Corporation, Dental Centre, Rumailah Hospital, Doha, Qatar

Address for correspondence: Prof. Hayder Abdalla Hashim, Hamad Medical Corporation, Rumailah Hospital, Dental Centre, Orthodontic Section, P.O. Box 3050, Doha, Qatar.
E-mail: hahashim78@yahoo.com

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dental cast.[8] Television images[9] and photographs of dental casts can be a reliable and efficient source of data in dentistry especially the intraoral camera. Laser holograms of the occlusal surface can be used for tooth-size measurement.[10,11] All of the above-listed methods are two-dimensional representations of a three-dimensional object. Thus, the advancement in computer technology permits the three-dimensional analysis of cast by means of stereophotogrammetry[12] and optocom.[13]

Dental casts are still considered as a vital diagnostic tool.[14] From the dental cast, one can analyze tooth-size and shape, alignment and rotations of the teeth, presence or absence of teeth, arch form and symmetry, and occlusal relationship.[15]

The importance of having a certain relationship between the maxillary and mandibular teeth drew the attention of the investigators over the years. Lundstrom[16] observed a large biological dispersion in the tooth-size ratio. It was great enough to have an impact on the final tooth position, teeth alignment overbite, and overjet in a large number of patients.

Bolton[5] published his analysis of mesiodistal tooth-size dimensions and their effect on occlusion. He selected 55 cases with excellent occlusion, most of these cases. Totally, 44 had been treated orthodontically without extraction. The ratio of the sum of mesiodistal widths of the 12 mandibular teeth divided by the sum of the 12 maxillary teeth was expressed as a percentage (91.3%). A similar value for the six upper and lower anterior teeth was also computed (77.2%). The arranged tables to predict the congruity between the maxillary and mandibular arches and concluded that this will result in an ideal overbite, ideal overjet, and ideal posterior occlusion.

Further, Bolton[5] showed the importance of analyzing mesiodistal tooth-size when he presented several cases to prove the effectiveness of his analysis clinically. He stated that the tooth ratios could without difficulty be made, a diagnostic aid, which allows the orthodontist to gain insight into the functional and esthetic outcome of a given cases without the use of the diagnostic setup. However, it was stated that; care must be taken in the use of this analysis since Bolton's formulae did not take into account quantitatively the incisors angulation.[5] However, other investigators have speculated that incisors inclination,[17] interincisal angle, labiolingual tooth thickness.[17,18] Overbite and overjet might influence ideal tooth-size relationship.[17] In spite of that many clinicians are using Bolton analysis as their primary guide for predicting tooth-size discrepancies.

Lavelle[19] investigated tooth-size ratio in different racial groups (Caucasoids, Mongoloids, and blacks; 40 cases in each group). He found that the overall and anterior ratios were greater among blacks than Caucasoids, whereas the Mongoloids were intermediate. He said this was confirmed from the percentage overbite, which although subjected to considerable variation, was greater in Caucasoids than blacks.

Crosby and Alexander[20] studied the occurrence of tooth-size discrepancies among patients with different malocclusions, Class II division 1 and division 2, and Class II surgical cases). They found no difference in the incidence of tooth-size discrepancies in different malocclusion groups. They observed, however, that a large number of patients within each group had tooth-size discrepancies greater than two standard deviation (SD) of Bolton's mean.

Lew and Keng[21] carried out odontometric measurement of anterior tooth crown size in a Chinese population sample with normal occlusion. They reported that tooth-size ratio for the six anterior teeth compared favorably with those originally published by Bolton[5] although the interincisal angle, overbite, and overjet were statistically different.

Hashim and Murshid[22] investigated the intermaxillary tooth-size ratio in Saudi subjects aged 13–20 years with the different type of malocclusions. Measurements of permanent teeth from first molar to a first molar in the other side were performed in 40 pairs of dental casts. The Bolton s formulae were used to examine the relationship between the maxillary and mandibular teeth. They found no significant difference in the mean of the tooth-size ratio of overall and anterior ratios when compared with Bolton's mean. Their study confirmed previous reports that different types of malocclusion do not affect the Bolton ratio.

Saatci and Yhkay[14] investigated the role of different type of tooth extraction in creating tooth-size discrepancies before treatment. They found that there was a difference between the pretreatment and postextraction values. Bolton's values were statistically significant for the first premolar extraction and insignificant for others. They concluded that the removal of the four first premolars created the most severe tooth-size discrepancies, whereas the extraction of all four-second premolars crated fewer discrepancies.

Rudolph *et al*.[18] reported that variation in labiolingual tooth thickness might produce inaccuracies in the Bolton analysis. They designed and tested a new formula that took into account the labiolingual tooth thickness for predicting anterior tooth-size discrepancies. They found that patient with thin incisor at the occlusion contact (<2.75 mm) had a stronger correlation with intermaxillary ratio than patient with thick teeth (>2.75 mm). The higher correlation coefficient for the thin teeth indicates that size discrepancies in these cases by using this method. In case of thick incisors; the sensitivity of this method in predicting tooth-size discrepancies will decrease and a diagnostic setup may be indicated.

Killiany[23] commented on Rudolph's method by noting that including the tooth thickness in the prediction model would improve the detection of intermaxillary tooth-size discrepancy. However, the analysis is still not as accurate as using a diagnostic setup (the gold standard for such predictors).

Nie and Lin[24] conducted a study in Chinese population to compare intermaxillary tooth-size discrepancies among different malocclusion groups for both sexes. They found a significant difference in tooth-size ratios between the groups in which Class III group had a higher mean value than Class I and Class II (Class III > Class I > CLASS II). However, sexual dimorphism for these ratios does not exist in each group.

Heusdens *et al*.[25] carried out an experimental study on the effect of tooth-size discrepancies on occlusion. They observed that severe tooth-size discrepancies affect the occlusion only a little, and the effect of generalized tooth-size discrepancies appears to be limited.

Basaran *et al*.[26] made tooth-size measurements on pretreatment models of patients with normal occlusion. The tooth-size ratios and the one-way analysis of variance test showed no sexual dimorphism for these ratios in each of five groups, so the sexes were combined for each group. Then, these ratios were compared among different malocclusion groups. The results show no significant difference between subcategories of malocclusion; therefore, these groups were combined as Class I, Class II, and Class III. No significant difference was found for all the ratios between the groups.

Al-Tamimi and Hashim[27] carried out a study among 65 Saudi military male subjects with Class I normal occlusion. The aim of the study was to establish tooth-size ratio and compare the result with Bolton's mean values and also between both sexes. In addition, they investigate whether there was a correlation between the interincisal angle and anterior ratio. They found that no significant difference between the mean values of overall and anterior ratio of their study and Bolton's and also between both sexes. Further, their result revealed a low correlation between the anterior ratio and interincisal angle. They suggested that Bolton's prediction tables can be used for Saudis until a large enough representative sample is studied to allow the drawing of prediction tables.

Uysal *et al*.[28] conducted study with the aim of identifying the possible sex differences in tooth-size ratios between males and females, to determine whether there is a difference in the incidence of tooth-size discrepancies for both the anterior and overall ratios when comparing with Angle Class I; Class II, division 1; Class II, division 2; and Class III malocclusion groups. Their result revealed that the significant sex difference was found only in the overall ratio for normal occlusion subjects ($P < 0.001$). All malocclusion groups showed statistically significant higher overall ratios than the normal occlusion group ($P < 0.001$). There were no statistically significant differences among malocclusion groups. They recommended that further investigations are needed to explain the probable racial differences and relationships between malocclusion and tooth-size measurements.

Mustaq and Tajik[29] conducted a descriptive study at the Dental OPD of KRL Hospital, Islamabad a sample of 120 patients who were selected using probability (simple random) sampling. They reported that the mean overall interarch tooth width ratio was 91.5, while mean anterior interarch ratio was found to be 79.02. *T*-tests to compare the ratios of this sample with the ratios of the Bolton sample showed that the difference was not significant for the overall interarch tooth width ratio ($P = 0.215$), while it was highly significant for the anterior tooth width ratio ($P = 0.00$). They concluded that Bolton's overall ratio of 91.3 can be applied on the KRL sample.

There are very few studies had been conducted on the tooth-size and dimensions in Sudanese population. However, no previous study investigated the intermaxillary tooth-size ratio (Bolton ratio) among the Sudanese. Hence, the objectives of this investigation were: To establish the overall and anterior ratio among the Sudanese population and to compare the result obtained with Bolton result and other studies in a different population. Further, to investigate whether there was a significant difference between males and females and the correlation between the overall and anterior ratio.

MATERIALS AND METHODS

Materials

The present study consisted of 60 pretreatment orthodontic casts of high school students (30 males and 30 females). The inclusion criteria were:

- All subjects were native Sudanese
- Age ranged from 15 to 20 years
- Class I molar and canine relationship
- Normal overjet and overbite
- No crowding, spacing, nor rotation of the teeth
- No large interproximal restoration
- No previous orthodontic treatment
- All permanent teeth are fully erupted in both jaws from the right first molar to the left first molar.

Methods

Impressions for both jaws for each subject were done using alginate (Alginplus fast. Italy). All impressions were poured immediately by stone (Model dental stone-type 3 C.Z). The dental casts were allowed to dry on a table for 1 h, and then numbered for identification. The casts were trimmed and prepared without being soaped.

Cast Measurement

The measurements were made directly on the dental casts. One operator took all measurements under the natural neon light. A caliper was used in the measurements.

The measurements were made as carefully as possible to avoid any damage to the cast using an electronic digital caliper to the nearest 0.01 mm.

The caliper beaks were inserted from the buccal (labial) and held occlusally parallel to the long axis of the tooth. The beaks were then closed until gentle contact with the contact points of the tooth was made.

The measurements included the mesiodistal width of 12 maxillary and mandibular teeth from the right first permanent molar to left permanent first molar.

To examine the tooth-size relationship between the maxillary and mandibular teeth, the Bolton formulae[4] were computed as follows:

$$\text{Overall ratio} = \frac{\text{Sum of mesodistal tooth width of mandibular 36 to 46}}{\text{Sum of mesodistal tooth width of maxillary 16 to 26}} \times 100$$

$$\text{Anterior ratio} = \frac{\text{Sum of mesodistal tooth width of mandibular 33 to 43}}{\text{Sum of mesodistal tooth width of maxillary 13 to 23}} \times 100$$

Assessment of Measurement Errors

Double measurements were performed in 10 orthodontic study casts randomly selected at 15 days interval from the collected sample by the same operator. This was to test the reliability of measurement.

Statistical Analysis

Student's *t*- and *t*-independent test were used to assess the error of the method, and the comparisons between males and females, and the result of the present study and Bolton's. The level of significance was $P < 0.05$.

RESULTS

Measurement Errors

The comparison was drawn between first and second determinations using Student's *t*-test. No significant differences were found between the two sets of measurements ($P > 0.05$).

Table 1 shows that the mean anterior ratio for the males was found to be 76.9 (SD 3.6), whereas for the females was 77.0 9 (SD 3.7).

Table 2 shows that the overall ratio for males was 91.0 with SD 3.9 whereas for the females was 90.6 with SD 3.1.

Table 3 demonstrated the mean of the overall and anterior ratio for the males and females combined. The mean of the overall ratio was 90.8 with SD 3.5 and for the anterior ratio 76.9 with SD 3.6.

Table 4 exhibited the statistical comparison of the overall and anterior ratio between the males and females. No statistical significant differences were observed between the two sexes at the 5% level of significance.

Table 5 presented that the means of the overall ratio and the anterior ratio of the present study were relatively similar to that reported by Bolton with a higher SD in the present study.

DISCUSSION

The mesiodistal tooth-size of the maxillary and mandibular arches must relate to each other to obtain an optimal occlusion at the completion of orthodontic treatment. If a patient has significant tooth-size discrepancy, orthodontic alignment into optimal occlusion may not be possible. Crosby and Alexander[20] and Freeman *et al*.[30] reported that a large percentage of orthodontic patients possess significant tooth-size discrepancies. Therefore, the orthodontist should be aware of these discrepancies before beginning orthodontic treatment.

Table 1: Bolton anterior ratio for males and females of the present study

Gender	Mean	SD	Sample size
Males	76.9	3.6	30
Females	77.0	3.7	30

SD – Standard deviation

Table 2: Bolton over all ratios for males and females of the present study

Gender	Mean	SD	Sample size
Males	91.0	3.9	30
Females	90.6	3.1	30

SD – Standard deviation

Table 3: Bolton overall ratio and anterior ratio for males and females combined

Ratio type	Mean	SD	Sample size
Overall ratio	90.8	3.5	60
Anterior ratio	76.9	3.6	60

SD – Standard deviation

Table 4: Comparison of overall and anterior ratios mean values of the present study between males and females

Ratio type	Gender	Sample size	Mean	SD	*P* value	*P*
Overall ratio	Males	30	91.0	3.9	0.0844	NS
	Female	30	90.6	3.1		
Anterior ratio	Males	30	76.9	3.6	0.865	NS
	Females	30	77.0	3.7		

NS – Not significant; SD – Standard deviation

Table 5: Comparison between the present study result and Bolton's mean values

Ratio type	Sample size	Mean	SD	*P* value	*P*
Overall ratio					
Present study	60	90.8	3.5	0.349	NS
Bolton study	55	91.3	1.91		
Anterior ratio					
Present study	60	76.9	3.6	0.562	NS
Bolton study	55	77.2	1.65		

NS – Not significant; SD – Standard deviation

The treatment alternatives for tooth-size discrepancies include restoration of relatively small teeth, inter-proximal stripping of relatively large teeth, modification of crown angulations or inclination, and extraction. Bolton[5] mentioned that overbite, overjet, and inter-incisal angle might influence ideal tooth-size relationships. However, no definite conclusions have been drawn as to the effect that overbite, overjet, and inter-incisal angle have on the accuracy of tooth-size analysis.

A review of the literature reveals that most of the studies in the tooth-size ratio were performed on a sample of both treated and untreated cases or on groups of orthodontic patients with malocclusion. Although the present study, was conducted on a sample of untreated subjects with normal Class I occlusion, the results show that the means of the overall ratio and the anterior ratio were in agreement with Bolton's results with the exception that the SD is slightly higher in the present study.

Crosby and Alexander[20] performed their study in orthodontically treated patient with different malocclusions (Class I, Class II division I, Class II division 2, and Class III surgery). They reported that no statistical significant differences in the incidence of tooth-size discrepancies among the malocclusion groups. However, in the present study only Class I malocclusion was considered. However, there was an agreement between the results of the present study and those reported by Crosby and Alexander.[20] Further, including different types of malocclusions, Hashim, and Murshid[22] investigated tooth-size discrepancies among Saudi patients. Their results were found to be in agreement with the result of the present study although the sample consisted of subjects having normal Class I occlusion. Furthermore, similar results have been presented by Nie and Lin[24] in a Chinese population. Consequently, no significant difference in tooth-size ratios was observed between the combined groups of malocclusion and normal occlusion.

Sexual and racial dimorphisms in the tooth-size ratio between Caucasian, blacks, and Mongoloid races have long been established. Lavelle[19] investigated tooth-size ratio in different racial groups (Caucasian, Mongoloid, and blacks) and also with different occlusal categories in both genders. He found that the overall and the anterior ratios were greater among the blacks race than the Caucasian race, with the Mongoloid race being intermediate. However, a significant difference was noticed between those of the blacks and the Mongoloid races. Further, he studied the degree of sexual dimorphism. He found that the overall and anterior ratios were greater in males, without mentioning whether the difference was significant or not. The difference in tooth-size ratio between genders was investigated in the present study, and result did not show statistical significance. When the results of the present study, were compared to the Lavelle study,[19] it was noticed that the overall and anterior ratios for Sudanese males and females were not significantly different from those of the Caucasian race. This is in agreement with the result obtained by Nie and Line.[24] However, Bolton's,[5] Stiffer[31] and Crosby and Alexander[20] did not consider gender and racial differences when analyzing tooth-size discrepancy.

In the current study, the interdependence between variables was investigated by the use of correlation coefficient. As the value of the correlation coefficient approach one, it indicates the correlation is high. Bolton[5] found that the correlation coefficient between the anterior ratio and overall ratio was 0.50, which was not a high correlation; however, he concluded that it was significant enough to encourage the development of his chart of tooth-size analysis. Contrary to Bolton findings, White[32] reported a low correlation ($r = -0.12$) between the overall and the anterior ratios. The correlation coefficient of the present study ($r = 0.79$) was high. This indicates that the result of the present study was highly significant than that of Bolton[5] and White.[32] The differences in sample selection (treated and untreated groups) and methods of the various studies could account for the dissimilar findings. However, an adequate explanation for the disparate results was not found.

Intermaxillary tooth-size discrepancies can be evaluated using a diagnostic set up or by prediction using a mathematical formula (Bolton analysis). As mentioned earlier; if the discrepancy was not detected initially, it may lead to embarrassing delays in the completion of the treatment at the finishing stage, or to a compromised and unstable result. Hence, Bolton analysis is an important diagnostic tool and one that should be the best used at the initial diagnostic stage in orthodontic therapy.

The results obtained in the present study indicate that the sample collected was belonging to the Caucasian race. However, the reality indicates that the Sudanese population consisted of different racial groups; therefore the firm conclusion is difficult to draw. Since this sample is not representative for the Sudanese population, hence, a further study with a large sample collected from the different parts of the Sudan is required.

CONCLUSIONS

The results of the present study led to the following:

- The means of the anterior ratio and the overall ratio were found 76.9 (SD 3.6) and 90.8 (SD 3.5), respectively
- There were no significant differences between Bolton's mean ratios of the present study and Bolton's study for overall ratio and anterior ratio
- There was no significant difference in Bolton's ration between males and females of the present study.

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Conflict of Interest

There are no conflict of interest.

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