Scientific

Bolton tooth size analysis in a sample of Nigerian adolescents

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Abstract

A correct proportion between the mesiodistal dimensions of the upper and lower teeth is crucial to achieving proper occlusal interdigitation with ideal overjet and a good molar intercuspation at the end of orthodontic treatment. **Aims and Objectives:** To determine mean tooth size ratios among a general population of Nigerians; determine the applicability of Bolton's mean tooth size ratios and prediction charts to the Nigerian population, and, to investigate gender differences in tooth size ratios. **Methods:** Three hundred and seventy-two school children (194 females, 178 males), aged between 12-16 years who met our criteria were selected from secondary schools. Measurements of the mesiodistal width of teeth from the central incisors to the first permanent molar in both arches were made from dental casts using a digital caliper. Mean, range and standard deviation of the anterior and overall ratios were computed for each subject. t- Tests were used to compare differences between the results of this study and those obtained by Bolton, and also to compare gender differences. **Results:** Tooth size ratios were determined as 78.59±3.73, and 92.09±2.73 for anterior and overall ratios respectively, and these ratios differed significantly from Bolton's. **Conclusion:** Bolton's mean ratios, and hence his prediction charts may not be applicable to Nigerians.

Key words: Bolton, Tooth size discrepancy, Tooth size ratios.

Introduction

A tooth size discrepancy (TSD) may be defined as a disproportion between the sizes of Individual teeth and is considered an important variable especially in the anterior segment[1]. An excellent orthodontic treatment result with optimal occlusion and ideal intercuspation, overjet, overbite is often jeopardized by a tooth size discrepancy or problematic tooth anatomy.[2] These problems of tooth size discrepancies are well known in orthodontics[3, 4,] and has even been described as the seventh key of occlusion.[5]

When the maxillary anterior teeth are too large in relation to the mandibular anterior teeth, clinical manifestations could present as a deep overbite, increased overjet or a crowded anterior maxillary segment. On the other hand, if the mandibular anterior teeth are too large in relation to the maxillary teeth, compensations on tooth positions include an edge to edge relationship, spacing of the maxillary anterior segment, mandibular incisor crowding or an improper occlusion of posterior teeth.[6] Occasionally, minimal anomalies are easily identified and treated. However significant TSDs can occur and be difficult to detect by mere inspection alone. Therefore the ability to analyze the proportionality of the maxillary and mandibular teeth to determine the degree and area in which a TSD occurs is essential, especially at the diagnostic stage.[6]

Over the years, several investigators have attempted to quantify the relationship between the upper and lower teeth,[7-10] however the tooth size analysis by Dr Wayne

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Bolton[11] remains the most popular and best known method for determining tooth size discrepancies. He evaluated 55 cases with 'excellent' occlusions, and derived two ratios of mandibular tooth material to maxillary tooth material, namely the Anterior Ratio and the Overall Ratio.

He concluded that these ratios should be two of the tools used in orthodontic diagnosis, allowing the orthodontist to gain insight into the functional and aesthetic outcome of a given case without the use of a diagnostic setup.He further drew up charts, based on his mean ratios, from which the amount of tooth excess or deficit in millimeters could be easily read off.

Though it may be reasonable to think that ideal tooth size ratios are related to various kinds of malocclusions, reports in literature remain varied.[12] Some authors[3, 7, 13, 14] have reported TSDs as being commoner in either the class III or class II div. I malocclusion group than in class I groups, some others[4, 11, 15-17] have reported otherwise. Uysal et al[17] studied patients with 4 different malocclusion groups, as well as a class I group as control. They demonstrated that no significant differences in prevalence of TSD existed among the all groups; however a large number of patients within each group had significant TSD. In addition, Akyalcin et al[18] in their study on 850 patients with different Angle's classes of malocclusion, concluded that molar relationship did not relate to intermaxillary discrepancies, and that Bolton TSD did not affect malocclusion this way. They suggested that other occlusal traits such as mid-line discrepancies and curve of Spee were probably more significant.

Race is also an important factor in variability of tooth size, and the general view is that tooth size varies with race due to differences in dental and skeletal morphologies,[3] and so specific norms and equations may conform only to the specific population from which it was drawn.[6] Different norms and standards have since been developed for different ethnic and racial groups.[3, 19-24]

Several studies[25-28] have shown that teeth in males are larger than those in females; however these differences in absolute tooth size cannot be assumed for tooth size ratios. While some authors[2, 19, 23, 29] have reported sex differences in tooth size ratios, some others[3, 13, 24] have concluded that sexual dimorphism does not exist with tooth size ratios.

Traditional methods of measuring tooth size include the use of needle – pointed dividers or a Boley gauge (Vernier Calipers) and a meter rule. Recent technological advances have however introduced digital calipers with LCD output, which has the advantage of eliminating vertical and horizontal measurement errors in reading off the meter rule. These digital calipers can also be linked to computers, utilizing various commercially available software for direct input and calculation of Bolton ratios, virtually eliminating measurement transfer errors.[30]

Tromasseti et al[31] evaluated the reproducibility of the manual method using the digital caliper, and 3 computerized methods. They found that no significant differences existed between the accuracy of the measurements, but that the computerized methods were much quicker to use, with the added advantage of prescribing the amount of correction required to produce ideal ratios for each patient. Digitalized or scanned images of study casts can also` be measured on-screen, also with the aid of specially designed software. This has several advantages including the ability to send virtual images to professionals anywhere in the world,[32] and saving money on storage space for models. Zilberman et al[33] also compared measurements with a digital caliper on stone models to those obtained from a virtual image with the OrthoCAD software. The OrthoCAD measuring tool shows a high accuracy and reproducibility, but was inferior to measurements done on study models with the digital calipers, though the latter was more time consuming. Digital calipers therefore seem to be a more suitable tool for scientific work, however, in practice; each Clinician must decide which method is acceptable and cost effective for his practice.[31]

The purpose of this study was therefore to determine mean tooth size ratios among a general population of Nigerians, determine the applicability of Bolton's mean tooth size ratios and prediction charts to a Nigerian population, and determine whether sexual dimorphism exists for tooth size ratios.

Materials and Methods

A total of 400 junior secondary school children from nine secondary schools in Lagos state, aged between 12 and 16 years old were included in this study. These subjects were carefully selected using the following inclusion criteria:

1) Both parents of Nigerian origin
2) Presence of fully erupted permanent teeth excluding 2nd and 3rd molars.
3) No dental anomalies
4) No evidence of tooth wear lesions, e.g. attrition
5) No interproximal caries or restorations
6) No previous or ongoing orthodontic treatment
7) No prosthetic tooth replacements or crowns.

Approval was obtained from the state Basic Education Board. Written consent was also obtained from parents / guardians of the students examined.

Alginate impressions of both upper and lower arches were made on each subject with PRO ALIGN Chromatic Alginate (P.S.P Dental Co. ltd, UK) using appropriately sized,

Table 1: Tooth size ratios of subjects.

Anterior ratio	Male	Female	Total
Mean(mm)	78.22	78.94	78.59
sd(mm)	3.38	3.99	3.73
Range ***t=1.88, p=0.06***	76.34-82.10	74.95-82.93	69.82-100.57
Overall ratio			
Mean(mm)	91.68	92.45	92.09
Sd	2.44	2.93	2.73
Range ***t=2.79, p=0.01****	89.24-84.12	89.52-95.38	79.22-101.43

*** Significant, sd=standard deviation.**

sterile, disposable impression trays. To ensure dimensional stability, the impressions were covered with damp gauze, during the short interval between when the impressions were taken, and the pouring of the models. The models were poured immediately after taking the impressions in the school premises, using dental stone, taking care to avoid air bubbles, defective borders or breakages. They were then labelled appropriately for easy identification.

Defective and poor quality casts, as well as those exhibiting more than 3mm of crowding were excluded.[30] Three hundred and seventy-two casts (178 of males, and 194 of females) which were of good quality, were measured using a digital calliper with LCD output [30, 31, 33] (Neiro tools, USA) set at 0.01mm accuracy, under natural light by a single author. The mesiodistal crown dimensions of all teeth (excluding the permanent second and third molars) were measured from one contact point to another at the largest mesiodistal dimension according to the method prescribed by Moorres.[34] Each tooth was measured twice, from right first molar to the left first molar in each arch.[20, 23, 28] An average of 10 casts were measured per day to prevent visual fatigue.[23]

To determine the errors associated with measurements, 30 models were randomly selected and re- measured after a 2 week interval from the first measurements by the same author.

Measurement errors were calculated according to Houston (1983)[35]: the Standard deviation of the mean difference between the initial and repeated measurements was calculated as an estimate of random error. Systematic error was determined using the paired – t test.

The index of reliability was the correlation between the initial and repeat measurements.

Data was entered into the Statistical Package for Social Sciences Software SPSS® for Windows version 16, SPSS Inc., Chicago, III., USA) on a personal computer. All mathematical calculations and statistical analyses were performed with the software. Bolton ratios were computed for each subject as follows:

(1) Overall Ratio (OR) which is the percentage relationship of the total mesiodistal width of mandibular teeth to the maxillary teeth.

$$OR = \frac{\text{Sum of mandibular 6-6}}{\text{Sum of maxillary 6-6}} \times 100$$

(2) Anterior ratio (AR) which is the percentage relationship of the total mesiodistal width of mandibular anterior teeth to the maxillary anterior teeth.

$$AR = \frac{\text{sum of mandibular 3-3}}{\text{Sum of maxillary 3-3}} \times 100$$

The mean, range and standard deviation of the AR and OR of study participants was compared to the results of Bolton's original study of Caucasians using the student's t-test, and its applicability to the Nigerian population determined.

Table 2: Comparison of tooth size ratios of present study with Bolton's study.

Anterior ratio	Present study	Bolton's study
n	372	55
Mean	78.59	77.2
Sd	3.73	1.65
Range ***computed t=4.72***	74.86-82.3 ***Critical t=1.96*, significant.***	75.55-78.85

Overall ratio

n	372	55
Mean	92.09	91.3
Sd	2.73	1.91
Range ***Computed t=2.65,***	89.26-94.82 ***Critical t=1.96*, significant.***	89.39-93.21

*** critical t at 95% confidence interval, df=425.**

Sexual dimorphism was detected using students-t test.

Differences were considered significant when the p-values were less than 0.05.

Results

The results are summarized in tables 1 to 4.

The mean anterior ratio was to 78.59±3.73% with a range of 74.86 to 82.33%, while the mean overall ratio was 92.09±2.73%, with a range of 89.36 to 94.82%. Both ratios were higher in females than in males, but only the overall ratio was significantly higher (Table 1).

Table 2 shows t-test comparison between the mean values from this study and those reported by Bolton. This table shows significant differences between both the mean anterior and overall ratios for the two studies.

A positive and significant correlation between the Anterior and Overall ratios was observed (r=0.67, p=0.00). Prediction tables were therefore set up to allow the prediction of the sums of teeth of one arch (anterior sum, and overall sum) from the other (Tables 3, 4)

Discussion

In this present study, tooth size ratios among a general population of Nigerian adolescents were investigated. Based on reports from several studies investigating effects of malocclusion type on the incidence of TSDs, which concluded that no significantly significant differences existed between TSDs and malocclusion type; the different classes of Angle's malocclusion types were not considered. The sample was randomly selected from junior secondary school children and thus proportionately representative of malocclusion type. Also, the relatively young age group of 12 – 16 years was to minimize effects of tooth wear like attrition, on mesiodistal tooth size.

The mean tooth size ratios derived from this study are higher than Bolton's values. This observation is also similar to those reported from a similar Nigerian study.[32] This also confirms the report of Smith et al,[19] who compared inter-arch tooth size relationships between 3 populations: whites, Blacks and Hispanics. The authors concluded that Blacks had the highest tooth size ratios, whites had the lowest, and the

Table 3: Prediction table for maxillary and mandibular anterior sums.

Maxilla	Mandible	Maxilla	Mandible
35	30.9	48	37.9
36	31.4	49	38.4
37	31.9	50	39.0
38	32.5	51	39.5
39	33.0	52	40.0
40	33.6	53	40.6
41	34.1	54	41.1
42	34.6	55	41.7
43	35.2	56	42.2
44	35.7	57	42.7
45	36.3	58	43.3
46	36.8	59	43.8
47	37.3	60	44.4

Hispanics were in between. These differences in tooth size ratios among different populations have been attributed to racial and ethnic differences in skeletal and dental morphologies.[3] Importantly Bolton's study was based on a Caucasian sample and hence cannot be relied upon for information regarding other racial groups. This study therefore confirms that Bolton's values, and his prediction tables, are not directly applicable to the Nigerian population.

The moderate, but significant correlation of 0.67, between the Anterior and Overall ratio, obtained in this study is higher than the 0.50 reported by Bolton,[11] also than that from a Saudi Arabian study[24] (0.59). This confirms the work of Lavelle[3], who reported that Negroid populations showed the highest degree of correlation between the sizes of upper and lower teeth, as compared with Caucasians and mongoloids, hence the formulation of prediction tables, suitable for the Nigerian population.

Both ratios were higher in females than in males, with difference only in the overall ratio being significant. This is difference in the Overall ratio consistent with reports from similar studies on both the Peruvian[23] and Turkish[29] populations. It however contrasts with those from the previous Nigerian study,[36] which reported no differences in both ratios between the sexes. This difference may be due to differences in sample selection. Both samples were from a general population, but were from different parts of Nigeria, with possible ethnic differences. Still, some other authors,[19, 20] have reported no differences in both ratios between the sexes in other parts of the world. These varied reports on sexual dimorphism and tooth size ratios have however been noted to be population specific, and so similar trends should not be expected for other populations.

Conclusion

1. Mean tooth size ratios were determined as 78.59% and 91.03% for anterior and overall ratios respectively.
2. Significant differenced exist between Bolton's mean tooth size ratios and those of this present study, therefore his tooth size ratios and prediction tables are not applicable to the Nigerian population.
3. Sexual dimorphism exists with tooth size ratios, being higher among females.

References

1. Proffit WR. Contemporary Orthodontics, 3rd Edition, Mosby, St Louis, p 170.
2. Araujo E, Souki M. Bolton Anterior Tooth Size Discrepancies among Different Malocclusion Groups. Angle Orthod 2002; 73: 307 – 313.
3. Lavelle CL Maxillary and Mandibular Tooth Size in Different Racial Groups and in Different Occlusal Categories. Am J Orthod.

Table 4: Prediction table for maxillary and mandibular total sums (6-6).

Maxilla	Mandible	Maxilla	Mandible
85	80.7	98	390.2
86	81.4	99	90.9
87	82.2	100	91.6
88	83.0	101	92.3
89	83.7	102	93.0
90	84.4	103	93.8
91	85.1	104	94.5
92	85.8	105	95.2
93	86.7	106	95.9
94	87.3	107	96.6
95	88.0	108	97.4
96	88.7	109	98.1
97	89.4	110	98.8

1972; 61:29-37.

4. Crosby DR, Alexander CG. The Occurrence of Tooth Size Discrepancies among different Malocclusion Groups. Am J Orthod Dentofacial Orthop.1989; 95:457-461.

5. Mc Laughlin MC, Bennet JC, Trevisi HJ. Systemised orthodontic treatment mechanics. Mosby, 2001; pg 285.

6. Al-Omari IK, Al-Biar, hamdan AM. Tooth Size Discrepancies among Jordanian school children. Eur J Orthod, 2008; 30:527-531.

7. Fattahi HR, Pashkir HR, Hedayati Z. Comparism of Tooth Size Discrepancies among Different Malocclusion Groups. Eur J Orthod 2006; 28:91-495.

8. Ballard ML .Asymmetry in Tooth Size in the Aetiology, Diagnosis and treatment of Malocclusion. Angle Orthod.1944; 14:67-71.

9. Neff CW. Tailored Occlusion with the Anterior Coefficient. Am J Orthod 1949;35:309-313.

10. Neff CW The size relationship between the maxillary and mandibular anterior segments of the dental arch, Am J. Orthod. 1957; 27:138-147.

11. Bolton WA. Disharmony in Tooth Size and its Relations to the Analysis and Treatment of Malocclusion. Am J Orthod 1958; 28:113-130.

12. Laino A, Quaremba G, Pauano S, Stanzione S. Prevalence of Tooth Size Discrepancies among different malocclusion groups. Prog. Orthod. 2003; 4:37-44.

13. Nie Q, Lin J. Comparison of Intermaxillary Tooth Size Discrepancies among Different Malocclusion Groups. Am J Orthod 1996; 166:539 -544.

14. Ciger S, Aksu M, Salgam-aydinatay. Interarch Tooth Size Relationships of Normal Occlusion and Class II division I Malocclusion Patients in a Turkish Population. Hacette Dishekimlgi Fakultei Dergisi, 2006; 30:25-32.

15. Uysal T, Saei Z, Bascifti FA, Memili B. Intermaxillary Tooth Size Discrepancy and Malocclusion: is there a Relation? Angle Orthod. 2004; 75: 208-213.

16. Al Sulaimani FFH, Afify AR. Bolton Analysis in Different Classes of malocclusion in a Saudi Arabian Sample. Egypt. Dent. J, 2006; 52:1119-1125.

17. Endo T, Abe Ryota, Kuroki H, Shimoola S. Tooth Size Discrepancies among different Malocclusions in a Japenese Orthodontic Population. Angle Orthod, 2007; 78:994-999.

18. Alyalcin S, Dogan Dincer B Erdnic AME, Oncag G. Bolton Tooth Size Discrepancies in Skeletal Class 1 individuals with different Dental Angle Classifications. Angle Orthod. 2005; 76:637-643.

19. Smith SS, Buschang PH, Watanabe E. Inter-arch Tooth Relationships of 3 populations. 'Does Bolton's Analysis Apply?' Am J Orthod Dentofacial Orthop 2000; 117:169-174.

20. Santoro M, Ayoub M.E, Pardi VA, Cangialosi TJ. Mesiodistal Crown Dimensions and Tooth Size Discrepancy of the Permanent Dentition of Dominican Americans. Angle Orthod 2000; 70:303-307.

21. Richardson ER, Malhorta SK. Mesiodistal Crown Dimensions of the Permanent Dentition of American Negroes. Am J Orthod 1975; 68: 157-164.

22. Merz ML, Isaacson R.J, Germane N, Rubenstein L.K. Tooth Diameters and Arch Perimeters in a Black and White Population. Am J Orthod Dentofacial Orthop 1991; 100:53-58.

23. Bernabe E, Flores-Mir C. Tooth-Width Ratio Discrepancies in a Sample of Peruvian Adolescents. Am J Orthod Dentofacial Orthod 2004; 125: 361-365.

24. Alkofide E, Hashim H. Intermaxillary Tooth Size Discrepancies

among Different Mal-occlusion groups, A Comparative Study. J Clin Pediatr Dent 2002; 24:383-387.

25. Arya BS, Savara BS, Thomas D, Clarkson Q. Relation of Sex and Occlusion to Mesiodistal Tooth Size. Am J Orthod. 1974; 66:479-486.

26. Sanin C, Savara BS .An Analysis of Permanent Mesiodistal Crown Size. Am J Orthod 1971; 59: 448-500.

27. Garn SM,Lewis AB, Kerewsky RS. Sex Difference in Tooth Size. J Dent. Rest. 1964; 43:306-307.

28. Bishara SE, Jakobsen JR, Abdallah EM. Comparisms of Mesiodistal and Buccolingual crown dimensions of the Permanent teeth in three populations from Egypt, Mexico, and the United States. Am J Orthod Dentofacial Orthop.1989; 96:416-422.

29. Uysala T, Serib Z .Intermaxillary Tooth Size Discrepancy and Mesiodistal Crown Dimensions for a Turkish Population. Am J Orthod Dentofacial Orthop 2005; 128:226-230.

30. Othman SA, Harradine NWT. Tooth Size Discrepancy and Bolton's Ratios: A Literature Review. J Orthod 2006; 33:45-51.

31. Tomasseti JJ, Taloumis LJ, Denny JM, Fischer JR. A Comparison of 3 Computerized Bolton Tooth Size Analyses with a Commonly Used Method. Angle Orthod 2001; 71:351-357.

32. Stevens DR, Flores-Mir C, Raboud DW, Heo G, Major PW. Validity, Reliability and Reproducibility of Plaster Vs Digital Study Models: Comparison of Peer assessment Rating and Bolton Analysis and their Constituent Measurements. Am J Orthod Dentofacial Orthop 2006; 129:794-803.

33. Zilberman O, Huggre JAV, Parikakis KA. Evaluation of Tooth Size and Arch-Width Measurements Using Conventional and Three-Dimensional Virtual Orthodontic Models. Angle Orthod 2003; 73:301-306.

34. Moores CFA, Reed RB. Correlations among mesiodistal Crown Diameters of Permanent Dentition of American Negroes. Am J Orthod.1969; 55:600-616.

35. Houston WJB. The analysis of errors in orthodontic measurements. Am. J. Orthod.1983: 382-390.

36. Ajayi EO. Bolton's ratios and tooth size discrepancies in a Nigerian population. Nig Dent J 2010; 18:21-23.