BOLTON'S ANTERIOR AND OVERALL TOOTH SIZE DISCREPANCY AMONG DIFFERENT MALOCCLUSION GROUPS IN CHENNAI POPULATION – AN EPIDEMIOLOGICAL STUDY

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CERTIFICATE

This is to certify that the dissertation entitled "Bolton's anterior and overall tooth size discrepancy among different malocclusion groups in Chennai population – an epidemiological study " done by ***Dr. MADHAN MOHAN.A*** *., post graduate student (M.D.S), Orthodontics (branch V), Tamil Nadu Govt. Dental College and Hospital, Chennai, submitted to the Tamil Nadu Dr.M.G.R.Medical University in partial fulfillment for the M.D.S. degree examination (April 2011) is a bonafide research work carried out by him under my supervision and guidance.*

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DECLARATION

I, **Dr. MADHAN MOHAN.A,** do hereby declare that the dissertation titled **"***Bolton's anterior and overall tooth size discrepancy among different malocclusion groups in Chennai population – an epidemiological study* **"** was done in the Department of Orthodontics, Tamil Nadu Government Dental College & Hospital, Chennai 600 003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfillment of the requirements for the degree of **Master of Dental Surgery** in the specialty of Orthodontics and Dentofacial Orthopedics (**Branch V**) during the course period **2008-2011** under the conceptualization and guidance of my dissertation guide, Professor and Head of Department, **Dr. W.S MANJULA, MDS.**

I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Nadu Government Dental College & Hospital.

I also declare that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work and I firmly affirm that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s).

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INTRODUCTION

The field of Orthodontics is being flooded by recent advances in diagnosis and treatment planning. However, the importance of basic model analysis, which can give information that no modern modality can give, keeps getting stressed now and then by various authors.

The major factor in coordinating posterior inter-digitation, overbite, and overjet in a neutro-occlusion, is the relative harmony in mesiodistal width of the maxillary and mandibular dentitions. The importance of this geometric relationship becomes apparent to orthodontists, especially in the finishing stages of a treated case.

Disproportionately sized teeth are, in some cases, easily recognizable. However, significant discrepancies can occur between the overall size of the maxillary and mandibular teeth that are difficult to identify by inspection alone. Bolton[17] in 1958, established an analysis to calculate the inter-arch discrepancy, both as overall and anterior ratios. Analysis of maxillary to mandibular tooth-width proportions (ratios) is an important diagnostic tool for predicting the final outcome of the occlusion after orthodontic treatment. An appropriate relationship of the mesiodistal width of the maxillary and mandibular teeth favours a good post treatment occlusion.

Andrews[6] (1972) indicated the importance of the ‘six keys’ of occlusion. The absence of any one or more of the keys results in an occlusion that deviates from normal. Bolton’s analysis gained an importance to an extent that McLaughlin[39] *et al.* (2001) stated that tooth size should be considered the ‘seventh key’ and that without coordination between the sizes of the upper and lower teeth, it would not be possible to obtain a good occlusion during the final stages of orthodontic treatment.

The purpose of orthodontic diagnosis and treatment planning is to determine the best possible functional and aesthetic results for the patient at the end of the treatment. In certain instances, when the appliances are removed, the patient may have spaces between the teeth an increased overjet and an increased overbite. These deviations from an ideal occlusion may be due to tooth size discrepancy between the maxillary and mandibular dental arches. Space gaining can be achieved in three ways: by expansion of dental arch, by lengthening of the dental arch and by extraction of the teeth or combination of the three.

The tooth size varies between different ethnic groups and as well as various malocclusion groups, and if these differences are not considered during initial stages of diagnosis and treatment planning, the challenges can be quite apparent at the finishing stage of the treatment.

The present study attempts to identify the possible variation of the Bolton’s ratio among different malocclusion groups and the gender related differences for the same in Chennai population.

AIMS AND OBJECTIVES

The aims and objectives of the study were

- To identify the possible gender related differences in tooth size ratios.
- To determine whether there is a difference in intermaxillary tooth size discrepancies among the malocclusion groups – Class I, Class II, and Class III classified by dental and skeletal variables.
- To determine the percentage of tooth size discrepancies outside 1 or 2 standard deviations from Bolton’s inter arch tooth size ratio.
- To compare anterior and overall ratios of different malocclusion groups in Chennai population with Bolton’s standard.

REVIEW OF LITERATURE

G. V. Black[16] in **1902** was one of the first investigators to become interested in the subject of tooth size. He measured large numbers of human teeth and set up tables of mean figures which are still important references today.

Young in **1923** compared two similar occlusions but found that the cases differed considerably in the amount of anterior over bite present.

The Lux brothers in **1930, Ritter (1933), Tonn (1937), Seipel**[61] **(1946), Selmer Olsen (1947)** etc have studied the maxillary & mandibular tooth widths & their relations.

According to **Andrews**[6] one mm mesiodistal tip of the anterior teeth will change the torque value by 4%.

Ballard[10] in **1944** studied asymmetry in tooth size; he measured the teeth on 500 sets of casts and compared the mesio-distal diameter of each tooth with the corresponding tooth in the opposite side of the dental arch. He advocated the judicious stripping of proximal surfaces, primarily in the anterior segments, when a lack of balance existed.

Ballard and Wylie[11] in **1947** provided a method of computing the total mesio-distal width of the un-erupted mandibular canine and premolars. This procedure was devised to be used in conjunction with Nance's method of mixed dentition case analysis, in which these measurements are taken from radiographs. A graph was formulated from which the mesio-distal width of the mandibular canine and premolars could be predicted after the total mesio-distal width of the mandibular incisors has been determined.

Neff[45] in **1949** used 200 cases and measured the mesio-distal diameters of both maxillary and mandibular teeth. He then arrived at an "anterior coefficient" by dividing the mandibular sum into the maxillary sum. The range was 1.17 to 1.41. He then attempted to relate the "anterior coefficient" to the degree of overbite, the overbite being determined by on a percentage basis by measuring the amount of coverage of lower central incisors by the upper incisors. By measuring normal occlusions which showed a 20% overbite, it was determined that the "anterior coefficient" for this figure was 1.20-1.22.

Steadman[66] in **1952** developed a method of predetermining the overbite and overjet relationship.

Rees in **1953** found that mesio-distal width of the maxillary teeth exceeded that of the mandible, and believed that the discrepancies could be reduced by stripping, extraction, or placing crowns.

Lundstrom[37] in **1954** showed a large biologic dispersion in the tooth width ratio, and said it was great enough to have an impact on the final tooth position, teeth alignment, and overbite and overjet relationships in a large number of patients.

Ballard in **1956** obtained the dimensions of teeth from the world's largest manufacturer of artificial teeth and found that the mesio-distal widths of the six mandibular anterior teeth were 75% of the mesio-distal widths of the six maxillary anterior teeth. He then advocated judicious stripping of the mandibular anterior segment to compensate for the tooth size discrepancy.

Bolton[17] in **1958** analyzed a group of 55 excellent occlusions. He introduced mathematical tooth size ratios, which were supposed to be helpful in diagnosis and treatment planning. Bolton concluded that these ratios should be 2 of the tools used in orthodontic diagnosis, allowing the orthodontist to gain insight into the functional and aesthetic outcome of a given case. His tables for anterior and overall tooth size ratios are still used today.

In a subsequent paper in **1962**, **Bolton**[18] expanded on the clinical application of his tooth size analysis. Bolton's standard deviations from his original sample have been have been used to determine the need for reduction of tooth tissue by inter-dental stripping or the addition of tooth tissue by restorative techniques.

George W.Huckaba in 1964 conducted a study on mixed dentition analysis in which the prediction of the size of the un-erupted permanent teeth and determining the amount of space in the dental arch which will be available for their eruption and concluded that if the existing dental occlusion is favourable and if space is adequate, then periodic examination to follow the course of growth and development to ensure a favourable adult dental occlusion is possible.

Lavelle[34] in **1972** studied tooth-size and ratios in Caucasoids, Negroids and Mongoloids. These 3 terms for these racial groups are originally anthropological and are based on skull dimensions. They can be considered equivalent to the terms white, black and far eastern as used in many English-speaking countries. Both the overall and anterior average ratios were greater in Negroids than in Caucasoids, those for Mongoloids being intermediate. The subjects were chosen to have excellent occlusions, so the means are a good guide to the ideal mean ratio to give a good fit for a racial group.

Peck and Peck in **1972** found statistically significant differences in both the mesio-distal (MD) and facio-lingual (FL) dimensions of mandibular incisors, between perfectly aligned and control populations of untreated females. Combining these measures into an index (MD/FL*100), they formulated ideal size ranges required for central and lateral incisors to be well aligned. They recommended MD reduction of incisors to place them within this range and prevent further crowding.

Richardson and Malhotra[53] in **1972** found that the teeth of black North American males were larger than those of females for each type of tooth in both arches, but there were no differences in anterior or posterior inter-arch tooth-size proportions.

Lavelle in **1977** did compare maxillary and mandibular tooth-size ratios between males and females. He showed that the total and anterior ratios were both greater in males than in females. However, these sex differences were small, all being less than 1%.

Sperry[65] **et al** in **1977** demonstrated that the frequency of relative mandibular tooth size excess (for the overall ratio) was greater in cases of Angles Class III.

John M Doris[21] **et al in 1981** conducted a study on a group of patients with good teeth aligned and a group of patients with crowded dental arches to compare mesiodistal tooth widths between them, and they concluded that the total mesio distal tooth size is uniformly larger in crowded arches.

However, **Gilmore and Little** in **1984** found that although there is a tendency for incisors with a greater mesio-distal dimension to be associated with crowding, the association was so weak that the reduction of the widths of incisors to fit a specific range cannot be expected to produce a stable alignment.

Crosby and Alexander[19] in **1989** found no difference in the incidence of tooth-size discrepancies in different malocclusion groups but showed that a large percentage of patients had mesio-distal tooth size discrepancies at pre-treatment Bolton tooth size analysis. They suggested that Bolton tooth size analysis was an important diagnostic tool and should be used for every orthodontic patient before initiation of treatment. They reported that 22.9% of subjects had an anterior ratio with a significant deviation from Bolton's mean (greater than 2 of Bolton's standard deviations). This is clearly a much higher figure than

Proffit's 5%. They also noted that there was a greater percentage of patients with anterior. TSD than patients with such discrepancies in the overall ratio. These findings are common to many investigations. Several studies have found that male teeth are larger than female teeth.

Bishara et al[15] is representative of these studies. In 1989, they compared boys and girls within and between 3 populations from Iowa, Egypt and Mexico. Canines and molars were significantly larger in boys than in girls. Regrettably, however, the TSD ratios were not measured in this or in many other studies. It is important to note that the possibility of gender differences in TSD is different from differences in absolute tooth size. The traditional methods of measuring mesio-distal widths of teeth on dental casts can be described as manual methods and have either employed needle-pointed dividers or a Boley gauge (Vernier callipers). In **1995, Shellhart**[62] et al evaluated the reliability of the Bolton analysis when performed with these 2 instruments and also investigated the effect of crowding on measurement error. They found that clinically significant measurement errors could occur when the Bolton tooth-size analysis is performed on casts that have at least 3 mm of crowding, a factor that should lead clinicians to undertake a TSD analysis in substantially crowded cases only when the teeth have been aligned.

Bishara[15] et al in 1995 determine the changes in the maxillary and mandibular tooth size-arch length relationship (TSALD) after the complete eruption of the deciduous dentition (X age = 4.0 years) to the time of eruption of the second molars (X age = 13.3 years). In addition, an attempt was made to determine whether TSALD in the permanent dentition can be predicted in the deciduous dentition. Records on 35 male and 27 female subjects were evaluated. In conclusion, the changes in the alignment of the teeth were primarily the result of a decrease in the available arch length in both the maxillary and mandibular arches. The correlations between the various deciduous and permanent parameters are of such a magnitude that does not allow an accurate prediction of the TSALD in the permanent dentition from the available dental measurements in the deciduous dentition. The clinical implications of the findings were discussed.

Halazonetis[25] in **1996** studied Bolton's ratio through the use of spreadsheets. The quantitative assessment of labio-lingual thickness of incisal edges, along with the importance of the curvature of the anterior arch segment, was evaluated in this study. These results may lead to several conclusions. The first concerns the use of the Bolton ratio in assessing any suspected tooth-size discrepancy. A low or high value may not necessarily reflect a true discrepancy and, similarly, an ideal value of 77% may not guarantee an ideal occlusion. Other factors may need to be evaluated as well. The second conclusion concerns the treatment options when a tooth-size discrepancy has been diagnosed. The model shows that a 1 mm overjet change may compensate for from 1 to more than 3 mm of arc discrepancy, depending on the anterior curvature. This finding may be of help in patients who have large teeth or pronounced marginal ridges of the upper incisors. In addition to overjet, changes in the curvature of the anterior segment may be useful. Where there is a deficiency in the upper arch, a flatter anterior segment may compensate for some of the discrepancy.

Freeman[24] et al in 1996 conducted a study to determine the percentage of orthodontic patients who present with an inter-arch tooth-size discrepancy likely to affect treatment planning or results. The Bolton tooth-size discrepancies of 157 patients accepted for treatment in an orthodontic residency program were evaluated for the frequency and the magnitude of deviation from Bolton's mean. Discrepancies outside of 2 SD were considered as potentially significant with regard to treatment planning and treatment results. Although the mean of the sample was nearly identical to that of Bolton's, the range and standard deviation varied considerably with a large percentage of the orthodontic patients having discrepancies outside of Bolton's 2 SD. With such a high frequency of significant discrepancies it would seem prudent to routinely perform a tooth-size analysis and incorporate the findings into orthodontic treatment planning. In the study by Freeman et al. it is noteworthy that the overall discrepancy was equally likely to be relative excess in the maxilla or the mandible, whereas the anterior discrepancy was nearly twice as likely to be a relative mandibular excess (19.7%) than a relative maxillary excess (10.8%).

Santoro[57](Mesiodistal crown dimensions and tooth-size discrepancy of the permanent dentition of Dominican Americans. **AngleOrthod 2000**); and **Araujo and Souki**[7] (Bolton anterior tooth size discrepancies among different malocclusion groups. **AngleOrthod 2003**) found similar prevalence values to Freeman.

Saatqi[55] **et al** in **1997** conducted a study to investigate whether the extraction of four premolars as a requirement of orthodontic therapy is a factor in the creation of tooth size discrepancies, and to determine whether any tooth extraction combinations create more severe discrepancies. The study is carried out on the pre-treatment dental casts of 50 patients with malocclusions. The dental casts were selected according to the main criteria. No tooth-size discrepancy between the mandibular and maxillary dental arches should exist before treatment. The difference between the pre-treatment and post-extraction Bolton values was found statistically significant for the first premolar extraction and insignificant for the others. The removal of the four first premolars created the most severe tooth-size discrepancy, whereas the extraction of all four second premolars created fewer discrepancies and the smallest range in the size of discrepancies. The results of this study indicate a new point of view to the question of which teeth to extract when evaluated for tooth size aspect only.

Ho and Freer[27] proposed that the use of digital callipers with direct input into the computer program can virtually eliminate measurement transfer and calculation errors, compared with analysis that requires dividers, rulers and calculators, although the same measurement error may be associated with the positioning of the callipers on the teeth. This is very analogous to the findings of investigations of manual and digitizer measurement of cephalometric lateral skull radiographs. However, a reproducibility study was not part of their paper.

Nie[44] et al in 1999 conducted a study to determine whether there is a prevalent tendency for intermaxillary tooth size discrepancies among different malocclusion groups. This study consisted of 60 subjects who served as the normal occlusion group and 300 patients divided into 5 malocclusion groups (i.e., Class I with bi-maxillary protrusion, Class II Division 1, Class II Division 2, Class III, and Class III surgery). Tooth size measurements were performed on the models of normal occlusion and pre-treatment models of patients by the Three Dimension Measuring Machine. A significant difference was found for all the ratios between the groups, the ratios showing that Class III > Class I > Class II. It demonstrated that inter-maxillary tooth size discrepancy may be one of the important factors in the cause of malocclusions, especially in Class II and Class III malocclusions. Thus this study proved the fact that Bolton analysis should be taken into consideration during orthodontic diagnosis and therapy.

Yoshihara[79] et al in **1999** investigated the relationships between tooth width, arch length, and irregularity index.

Maxillary dental casts from 32 subjects who had undergone only serial extraction were analyzed at 3 stages: before deciduous canines' extraction, after first premolars extraction, and at the end of the observation period. They concluded that

1. The mean of the irregularity index decreased significantly as serial extraction proceeded and further decreased during the observation period.
2. There was a significant negative correlation between the irregularity index at T1 (before deciduous canines extraction) and correction of irregularity index from T1 to T2 (after first premolars extraction) and a significant negative correlation between the irregularity index at T1 and correction of irregularity index from T1 to T3 (the end of the observation period).
3. In cases where the width of the incisor was more than 2 SDs above the means for the control subjects, there was a significant correlation between tooth width of the lateral incisors and irregularity index at T1 and a significant correlation between the summation of tooth

widths of the central and lateral incisors and irregularity index at T1. There was also a significant negative correlation between the tooth width of the lateral incisors and correction of the irregularity index from TI to T2.

4. There was a significant negative correlation between ALD and irregularity index at T1 and also a significant correlation between ALD and correction of the irregularity index from T1 to T2.

Smith[64] et al in **2000** stated that specific dimension relationships must exist between the maxillary and mandibular teeth to ensure proper inter-digitation, overbite and overjet. Within certain limits, this would seem self-evident, yet amongst orthodontists, opinions vary widely concerning the frequency of significant TSD and the need to measure it in clinical practice.

Heusdens, Dermaut and Verbeeck[26], in **2000** conducted a study to compare the anterior and overall ratio values reported by Bolton (ideal occlusions) to the calculated values from data in other epidemiological studies (mesiodistal widths), to assess the accuracy of TSD measurements on dental casts compared with epoxy models, to investigate to what extent generalized TSD affects occlusion, to investigate the effect on occlusion of leveling the curve of Spee, and to investigate the effect of extraction therapy on the final occlusion. They concluded that

1. The overall ratio calculated by Bolton on models in patients with an ideal occlusion is representative for the calculated overall ratios starting from tooth width values reported in epidemiologic studies. However, the anterior ratio in epidemiologic studies was somewhat higher than Bolton's ratio possibly because of a greater morphologic variability in upper incisor width.
2. There was no statistical difference between the measurements on epoxy resin models or plaster models. Both materials are suitable for TSD studies. The reproducibility of the TSD measurements was found to be very high (99%).
3. The PAR index in all the setup situations varied between 0.05 and 7.2, indicating that only minor

malocclusions were found. Even in severe TSD cases, an acceptable Class I molar relationship with a reasonable overjet and overbite was found.

4. An excessive curve of Spee (6 mm) creates the poorest setup result.
5. Extraction therapy only slightly affected the final occlusion, whereas the calculated overall values indicated a maximum discrepancy of 2 mm. They evaluated the effect of the introduction of a deliberate TSD on a typodont occlusion. The typodonts were set up to produce the 'best' occlusion possible in the light of the extractions or deliberate introduction of TSD. Crucially, and perhaps understandably, the effect on occlusion was measured by the size of the PAR score achieved in the set-up. They reported that extraction therapy only slightly affected the PAR score of the final occlusion, which is to be expected. Much more surprisingly, they concluded that a TSD of 12 mm from Bolton's average could still permit a satisfactory occlusion as measured by PAR and that, therefore, TSD was not a real factor in the inability to produce a

good occlusion. It is intuitive to believe that a discrepancy of 12 mm cannot permit a good occlusion by most standards. This study is an interesting and potentially informative approach, but probably reveals more about the potential insensitivity of the weighted PAR index than it does about the degree of TSD that is clinically significant.

Tomassetti[69] et al in **2001** performed a study using manual measurements with a Vernier calliper and 3 computerized methods. Quick Ceph was the quickest method followed (in order) by HATS, OrthoCad and Vernier callipers. However, Quickceph gave results which gave the greatest mean discrepancy from Vernier callipers (although not statistically significant) and which were least correlated with the Vernier calliper results. Although these findings are helpful, the authors did not measure the reproducibility of each method by means of replicate measurements.

Tu An Ta[71] et al in 2001 compare Bolton anterior and overall ratios among different occlusion groups of southern Chinese children. For the anterior ratio, a statistically significant difference was found between the Bolton standard and the Class III occlusion group. For the overall ratio, statistically significant differences were found between the Bolton standard and the Class II occlusion group, and between the Class II and the Class III occlusion groups. Thus specific standards are required for Class II and Class III cases from the southern Chinese population.

Lindsten et al in 2002 compared the dental arch space and permanent tooth size in the mixed dentition of a skeletal sample from the 14th to the 19th centuries and 3 contemporary samples. A smaller permanent tooth crown size was found in the mixed dentition of children from the 14th to the 19th centuries compared with contemporary children living in the same country. The lateral arch length from the first permanent molar to the lateral incisor is generally smaller in the group born in the 1960s because of its greater caries prevalence. The relative space (arch perimeter minus tooth size) is deviant in the group born in the 1960s. There is a small number in the skulls in the relative space registration, but no statistic indicates that crowding is more prevalent in the groups born in the 1980s than in the skulls. The group born in the 1960s had less favourable relative dental arch space because of the greater caries prevalence.

Santoro[58] et al in 2003 evaluated the reliability of the OrthoCAD system in assessing malocclusion. Two independent examiners measured tooth size, overbite, and overjet on both digital and plaster models. No difference was found between the 2 groups in the measurement of overjet. Inter-examiner reliability was consistent for both the plaster and the digital models.

Puri[51] et al in **2003** conducted a biometric study to examine the extent to which tooth size contributes to dental crowding or spacing. They concluded that mesio-distal tooth size is an important factor in the assessment of crowding or spacing and in orthodontic treatment planning.

Warren[75] et al in **2003** compared the tooth size discrepancy between the historical and contemporary samples**.** The results indicated that tooth sizes were generally similar in the 2 cohorts but slightly larger in contemporary children. Crowding, as measured by TSALD, was found to be common in the mandibular arch for contemporary children in the deciduous dentition of both boys and girls. Moreover, crowding was much more common and severe in contemporary children compared with children in the historical cohort. Further research is needed to determine whether the increase in mandibular crowding in the deciduous dentition will continue to be observed in the mixed and permanent dentitions and to further establish these possible secular trends.

Lestrel[36] et al in **2003** compared the shape of crowded and uncrowded dental arches, matched for size and sex. The application of elliptical Fourier functions (EFFs) provided an accurate numeric description of the dental arch form. From photographs, a set of 24 homologous points describing the tooth row was identified. These points were then fitted with EFFs. Each maxillary and mandibular outline was subsequently standardized for size by scaling the bounded area to a constant 10,000 mm2. These “shape only" data were used to assess differences between arches in the 2 groups. By multivariate analysis of variance, statistically significant shape differences between groups I and II were obtained for both arches. Patients with crowding exhibited more variability than did the controls. This study has demonstrated the usefulness of EFFs for numerically describing the shape of structures in the craniofacial complex, specifically the MX and MD arches. With the use of such procedures as EFFs, it might become feasible to develop standards of dental arch shape. Such clinical standards might prove useful for orthodontic, prosthodontic, and oral surgery treatment planning.

Zilberman[80] **et al** in **2003** also compared the measurement using digital callipers with OrthoCAD. Measurement with digital callipers produced the most accurate and reproducible results, but these were not much improved relative to the results with OrthoCad. Digital callipers seem to be a more suitable instrument for scientific work, but OrthoCAD's accuracy was considered clinically acceptable.

Liano[32] **et al** concluded that there was no association between TSD and the different malocclusion groups, but with only 13 subjects in their Class III group, statistically significant differences were improbable.

Arkutu[8] in **2004** evaluated commonly used means of assessing a Bolton's discrepancy to the gold standard, which was defined as the measurement with a Vernier calliper to 0.1 mm. Anterior and overall ratios were calculated using 4 methods:

- 'eyeballing' (simply looking);
- a quick check by comparing the size of the laterals and second premolars;
- callipers and stainless steel ruler (0.5 mm);
- Vernier callipers (0.1 mm).

Sensitivity and specificity tests were performed and the study found that, when compared with actual measurement with callipers, these rapid, visual tests are poor at detecting a lack of Bolton discrepancy and very poor at correctly identifying a significant Bolton's discrepancy. This may further explain the subjective clinical view that significant

TSD is much less common than several studies have reported.

Bernabe[13]**´et al** in **2004 determined** maxillary to mandibular tooth-size ratios in a Peruvian sample; 200 children were selected who had complete permanent dentition, without clinically visible dental caries or proximal restorations, and no previous or active orthodontic treatment. There were clinically significant tooth-size discrepancies in almost one third of the sample. The 2-standard deviation range from the Bolton standard did not predict clinically significant anterior and total tooth-width ratio discrepancies.

Tong[70] **et al** in **2004** investigated whether the extraction of 4 premolars as a requirement of orthodontic therapy is a factor in the creation of TSD. Pre-treatment mesio-distal dimensions of mandibular and maxillary teeth were measured, recorded on a computer program and subjected to Bolton's analysis. They then performed hypothetical tooth extraction of all premolar combinations by computer on each patient. Their results are in agreement with the opinion expressed by Bolton8 that the removal of the larger mandibular second premolars often improves the overall Bolton ratio. This factor is not large, but may tip the balance in some extraction decisions.

Bernabé, Castillo and **Flores-Mir**[14] in **2005** conducted a study to identify the intra-arch occlusal characteristics that best discriminated 3 groups with different grades of dental arch discrepancies. Intra-arch measurements were made on 150 sets of dental casts of high school students (aged 12-16; 75 boys, 75 girls). Stepwise multiple discriminant analysis (SMDA) was used to obtain a better understanding of the morphological relationships between tooth and dental-arch variables and their relationship with crowding. They concluded that although other tooth-size and arch dimensions are indicators of crowding, arch length is the most important factor.

Kayalioglu[31] **et al in 2005** report a mathematical tooth-size ratio specifically designed for patients needing the extraction of 4 first premolars and to compare the anterior “6” and overall “12” ratio values reported by Bolton with the calculated anterior "6" and overall "10" ratio values obtained from data in this study. This study was conducted in 3 phases. In the first 2 phases, authors used the peer assessment rating and ideal cephalometric norms to select 53 ideal post-treatment models of patients who had had 4 premolars extracted. In the third phase, the mean overall "10" ratio and the mean anterior "6" ratio were calculated for the selected models. The mathematical tooth size overall ratio of 89.28% was determined for patients requiring the extraction of 4 first premolars and was recommended for use in diagnosis and treatment planning.

Al-Tamimi and Hashim[5] in **2005** also found no sexual dichotomy in Bolton ratios in a relatively small sample of 65 Saudi subjects. In contrast Smith et al found that males had larger ratios than females. However, these differences (0.7% for overall ratio and 0.6% for anterior ratio) were small, being much less than 1 standard deviation from Bolton's sample. Most studies have therefore found no differences in the mean Bolton ratios between the sexes and in those studies which have found a difference, it has been small, with males having slightly larger ratios.

Paredes[50] et al in 2006 conducted a study to determine the Bolton ratios in Spanish subjects. They concluded that differences between Spanish values and Bolton’s were significant, and specific standards for Spanish people might be needed.

Mullen[43] et al in **2007** conducted a study to determine the accuracy and speed of measuring the overall arch length and the Bolton ratio, and the time to perform a Bolton analysis for each patient by using software (emodel, version 6.0, GeoDigm Corp, Chanhassen, Minn) compared with hand-held plaster models. The mesiodistal width of 30 teeth from first molar to first molar was measured to the nearest 0.1 mm with digital calipers, and the Bolton ratio was calculated for each patient. The times required to make the measurements and to perform the analysis were recorded in seconds by using a stopwatch. He concluded that when performing a Bolton analysis, the e-model can be as accurate as, and significantly faster than, the traditional method of digital calipers and plaster models.

Lee[35] **et al** in **2007** established normative data on tooth size with a clustering method. Dental casts of 307 subjects with normal occlusion were examined. In these subjects, the tooth-size data sets in the maxilla and the mandible were clustered for men and women by using multivariate normal mixture models. The method used in this study seems to provide a more substantive design for artificial teeth and add an additional dimension in the process of diagnosis of patients. Further applications seem possible in dental anthropometry by simultaneously dealing with the full dentition as a data set.

Akcam[2] **et al** in **2008** evaluated 3-dimensional (3D) tooth crown sizes in patients with cleft lip and palate (CLP) and to compare them with those of a Class I control group. They concluded that in general, MD, LL, and OG dimensions of CLP patients were smaller than those of the Class I subjects, not only in the affected maxillary dental arch, but also in the mandibular dental arch. Variations in 3D tooth dimensions were found among all CLP types. The lateral incisor in the cleft region was the smallest. A 3D tooth-size evaluation should be included in the diagnostic records to determine precise treatment planning and final occlusion in CLP patients.

Agenter[1] **et al** in **2009** conducted a study to test whether the dimensions of the crowns of the permanent teeth differ in young men with naturally good occlusions compared with those who required orthodontic treatment. They concluded that tooth size is not necessarily the foremost cause of malocclusion in a patient, but it should be evaluated.

Uysal[72] **et al** conducted a study to establish new regression equations derived from 228 Turkish patients (100 boys, 128 girls) with no intermaxillary tooth-size discrepancy that would give the greatest correlation coefficient for the sum of permanent tooth widths of the canines and the premolars of both jaws, according to sex. There were statistically significant sex differences in tooth sizes in a Turkish sample. Boys had significantly larger teeth than girls, as shown by the differences in the summations of the widths of the mandibular incisors, and the maxillary and mandibular canine and premolar segments in both arches. No significant right-left differences of the posterior summations were found; thus, averages of both were used. In this study, new linear regression equations were developed based on the measurements of 228 patients without inter-maxillary tooth size discrepancy, by using the widths of the 4 mandibular permanent incisors as predictors for the sum of the widths of mandibular permanent canines and premolars during the mixed dentition for a Turkish population.

Endo,Ishida,Shundo, Sakaeda, and **Shimooka**[22] in **2010** investigated the effects of premolar extractions on the Bolton overall ratios and overall tooth-size discrepancies in a Japanese orthodontic population. Mesio-distal tooth widths were measured on 198 pre-treatment dental casts of subjects with Class I, Class II, and Class III malocclusions. The overall ratios and tooth-size discrepancies were determined before and after hypothetical premolar extractions. Extractions were performed in the following combinations: (1) all first premolars, (2) all second premolars, (3) maxillary first and mandibular second premolars, and (4) maxillary second and mandibular first premolars. They concluded that in formulating a treatment plan involving premolar extractions, orthodontists should consider that the overall ratios might decrease, and normal and clinically significant tooth-size discrepancies could change mutually after extractions.

MATERIALS AND METHODS

STUDY DESIGN

This is an observational and cross sectional study, documenting prevalence of tooth size discrepancy among different malocclusion groups in Chennai population.

SAMPLING

Two hundred and thirty eight study models were randomly selected from archives of the department of orthodontics, Tamil Nadu Government Dental College and Hospital, Chennai, Tamil Nadu. All the subjects were between 14 to 28 years of age. The samples were divided into three groups based on Angle’s classification of malocclusion – class I, class II Div I, and class III, coinciding with skeletal relationship, which was based on the steiner’s ANB angle: class I 0<ANB <5; class II ANB >5 and class III ANB <o. Each of these groups was again divided into two groups- male and female.

CLASS	MALE	FEMALE	TOTAL
Class I	65	64	129
Class II	39	40	79
Class III	15	15	30

SELECTION CRITERIA

The inclusion criteria were

1. Good-quality pretreatment models
2. Complete permanent dentition from first molar to first molar in both arches;
3. No tooth deformities;
4. No partially erupted teeth;
5. No size alterations of teeth;
6. No mesiodistal and occlusal abrasion, caries, or class ii restorations; and
7. Equivalent dental and skeletal classifications.

EXCLUSION CRITERIA

The rejection criteria were

1. Gross restorations, buildups, crowns, onlays, Class II amalgams, or composite restorations that affected the tooth's mesiodistal diameter
2. Congenitally defective or deformed teeth
3. Interproximal or occlusal wear to teeth; and
4. Congenitally missing teeth or any missing permanent tooth from first molar to first molar.
5. Previous orthodontic treatment

METHODOLOGY

Digital vernier calliper, accurate to 0.01 mm, was used for measuring the mesiodistal widths of all teeth from first molar to first molar on each cast. The mesiodistal width of each tooth was measured at the greatest distance between the contact points on the proximal surfaces. All measurements were done by 1 investigator. The sum of maxillary and mandibular anterior tooth size and the sum of all mesio-distal tooth size from first molar to molar were calculated, and the inter arch tooth size discrepancy was calculated using Bolton's analysis.

CALCULATION

Overall ratio =

$$\frac{\text{Sum of mesiodistal widths of mandibular 12 teeth (first molar-first molar) x100}}{\text{Sum of mesiodistal widths of maxillary 12 teeth (first molar-first molar)}}$$

Anterior ratio =

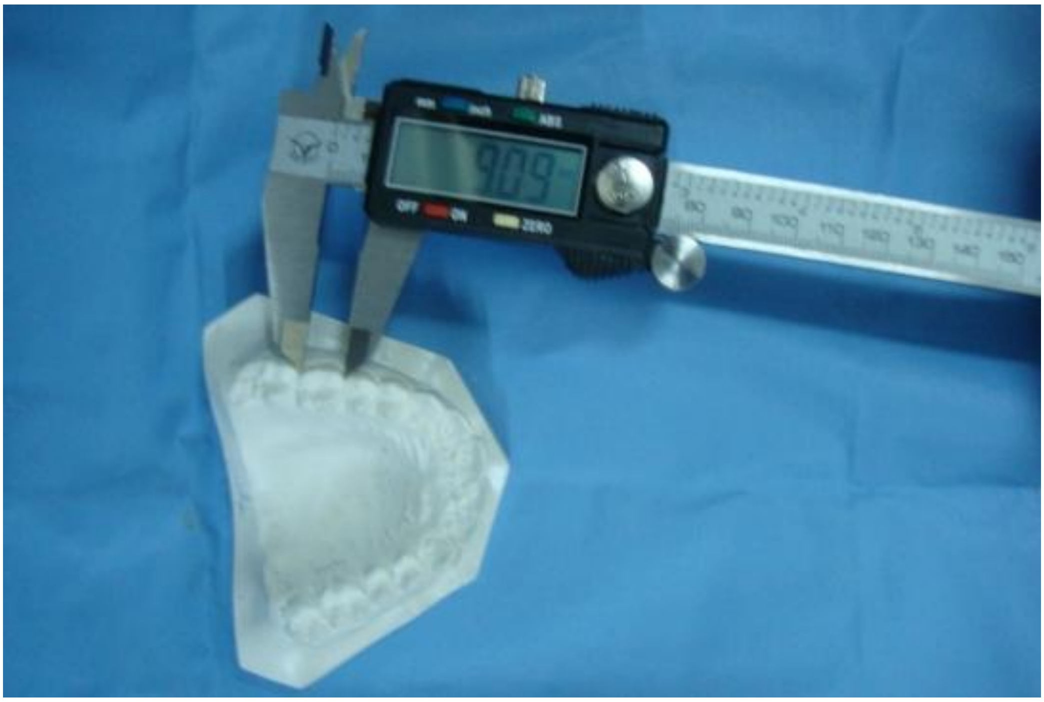
$$\frac{\text{Sum of mandibular anterior 6 teeth x100}}{\text{Sum of maxillary anterior 6 teeth}}$$

ANALYSIS OF ERROR

The same investigator performed all measurements, and the reproducibility of the method was tested. A total of 30 models (10 Class I, 10 Class II, and 10 Class III) were randomly selected from the original sample, and measurements were repeated twice within a three-week interval. No significant differences between the two sets of measurements ($P > .05$) (Table 1) were found upon testing using the Wilcoxon nonparametric test.

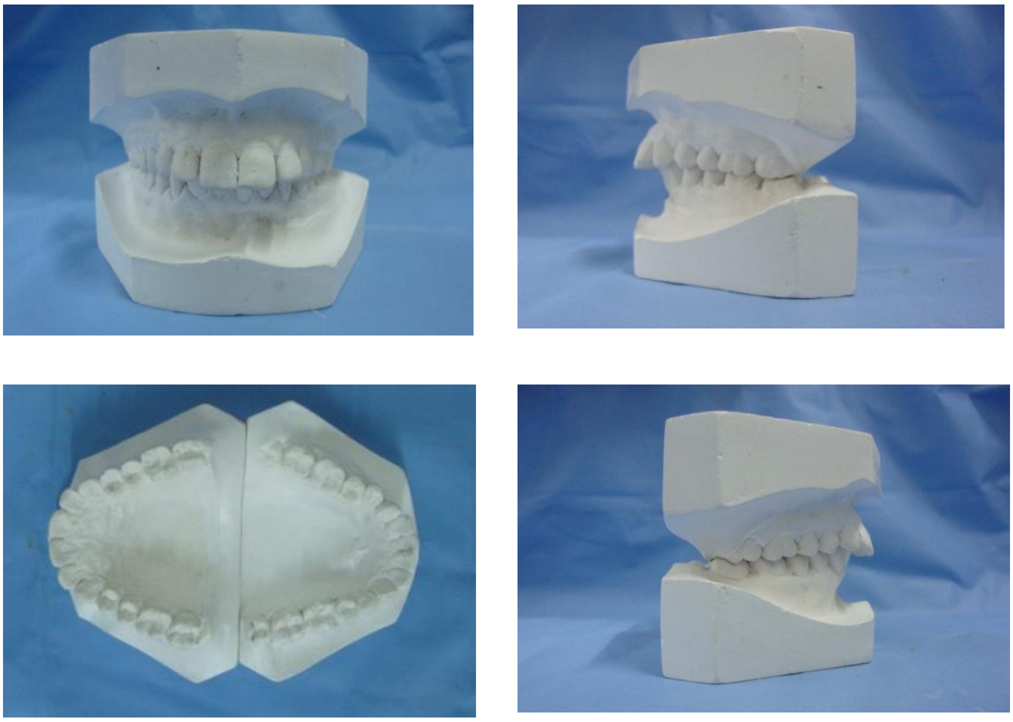
PHOTOPLATE 1 Sample models

PHOTOPLATE 2 Digital Vernier Caliper illustrating measurement technique

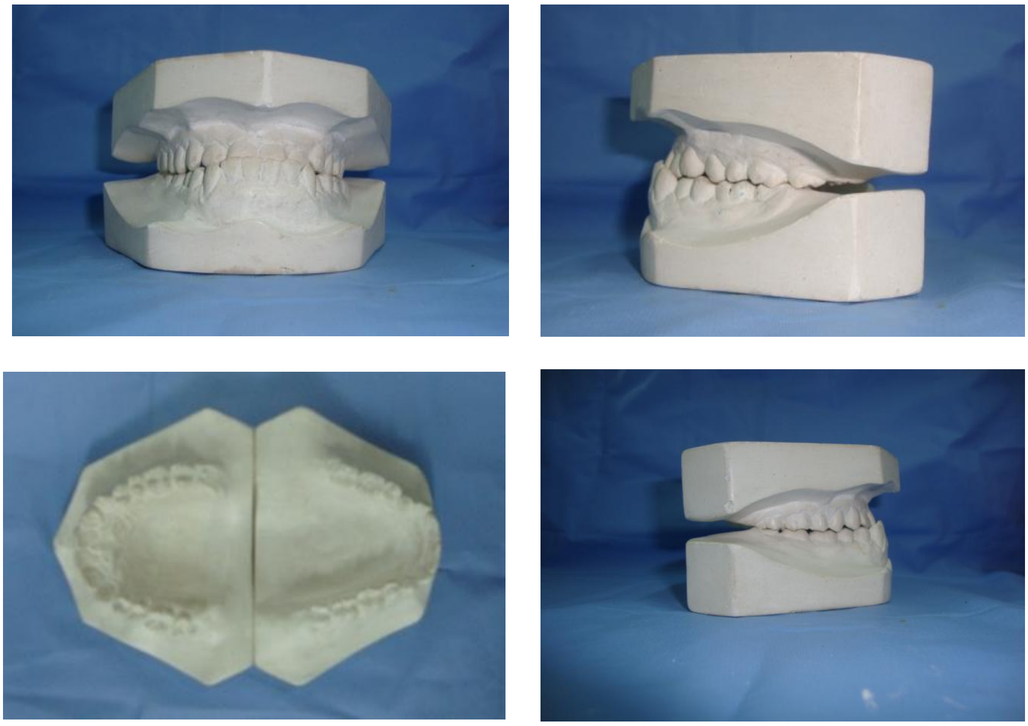


PHOTOPLATE 3 Class I malocclusion models

PHOTOPLATE 4 Class II malocclusion models



PHOTOPLATE 5 Class III malocclusion models



RESULTS

BOLTON'S TOOTH SIZE DISCREPANCY AND GENDER

Anterior and overall ratios for Bolton's tooth size discrepancy for males and females are presented in Table 2. Independent sample "t" test was done to find the gender difference. There were no statistically significant differences between males and females for the anterior and overall ratios.

PREVALENCE OF TOOTH SIZE DISCREPANCY

The frequency of tooth size discrepancy 1, 2, and more than 2 SD from Bolton's mean for anterior and overall ratios are shown in Table 3, 4 and chart 1 through 8.

A total of 57.1% of the subjects in this study presented Bolton tooth size discrepancies greater than ±1 SD for overall ratio and 68% for anterior ratio. Tooth size discrepancies greater than ±2 SD were considered to be clinically significant. In the present study, clinically significant discrepancies were found in 27.7% of the sample for overall ratio and 42.4% of the sample for anterior ratio of Bolton's analysis.

When analyzed by Angle classification, Class III malocclusion group showed greater prevalence of tooth size discrepancies greater than 2 standard deviation (anterior ratio-53.3% and overall ratio-40%) compared to class II(anterior ratio-41.8% and overall ratio-24%) and class I(anterior ratio-40.3% and overall ratio-27.1).

COMPARISONS BETWEEN THE DIFFERENT MALOCCLUSION GROUPS OF CHENNAI POPULATION

Bolton's Anterior and Overall ratios for Class I Class II and Class III malocclusion are presented in Table 5. Oneway ANOVA test showed no statistically significant differences (P>0.05) in the Bolton anterior and overall ratios between the different malocclusion groups.

COMPARISON OF ANTERIOR AND OVERALL RATIOS AMONG DIFFERENT MALOCCLUSION GROUPS OF CHENNAI POPULATION AND BOLTON'S STANDARDS

One sample test revealed a statistically significant difference ($P<0.05$) between the anterior ratio of Bolton's standard and the Class I and Class III malocclusion group. The anterior ratio of 16 cases out of 30 (53.3%) from the Class III malocclusion group and 52 cases out of 129 (40.3%) from the Class I malocclusion group fell more than 2 standard deviations from the Bolton standards. The values are shown in table 3, 4 and 6; and chart 9.

TABLE 1 Analysis of Error for All Measurements Submitted to Nonparametric Wilcoxon Statistical Testing Demonstrating No Significant (P > .05) Difference Between the Two Sets of Measurements

GROUP	MEASUREMENT	n	DESCRIPTIVE MEASUREMENTS				P VALUE
			MINIMUM	MAXIMUM	MEAN	SD	
Class I	1	10	74.0	82.0	78.2	2.6	0.760
	2	10	75.2	83.0	78.4	2.6	
Class II	1	10	73.5	83.9	78.0	2.8	0.155
	2	10	74.5	83.9	78.9	2.9	
Class III	1	10	75.8	80.0	78.2	1.4	0.838
	2	10	75.9	80.2	78.2	1.3	

TABLE 2 The mean and standard deviation (SD) for the anterior and overall tooth size discrepancy for males and females – Independent sample test demonstrating no significant(p>.05) sexual dimorphism.

		Gender				
		Male		Female		
		Mean	SD	Mean	SD	P Value
Class I	Anterior Ratio	78.65	4.82	78.59	4.89	0.937
	Overall Ratio	90.67	4.92	90.51	3.58	0.831
Class II	Anterior Ratio	78.13	5.74	78.10	4.39	0.979
	Overall Ratio	91.79	3.94	91.06	4.12	0.422
Class III	Anterior Ratio	79.79	3.29	79.35	4.04	0.747
	Overall Ratio	93.41	7.07	90.69	3.94	0.207

TABLE 3 The percentage distribution of anterior tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's means.

class	Outside 2 SD(%)	2SD(%)	1SD(%)	Mean	1SD(%)	2SD(%)	Outside2SD(%)
	<73.9	73.9-75.4	75.5-77.1	77.2	77.3-78.8	78.9-80.5	>80.5
Class I	13.2	8.5	20.2	0	13.2	17.8	27.1
Class II	12.7	11.4	13.9	0	16.5	16.5	29.1
Class III	10	0	20	3.3	6.7	16.7	43.3

40.3% of class I outside 2 SD
41.8% of class II outside 2 SD
53.3% of class III outside 2SD

66.6% of class I outside 1SD
69.6% of class II outside 1SD
70.0% of class III outside 1SD

TABLE 4 The percentage distribution of overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's means

class	Outside 2 SD(%)	2SD(%)	1SD(%)	Mean	1SD(%)	2SD(%)	Outside2SD(%)
	<87.5	87.5-89.3	89.4-91.2	91.3	91.4-93.2	93.3-95.1	>95.1
Class I	17.8	14.7	24.8	0.8	20.2	12.4	9.3
Class II	11.4	16.5	17.7	1.3	20.1	20.3	12.7
Class III	13.3	3.3	23.3	0	16.7	16.7	26.7

27.1% of class I outside 2 SD
24.1% of class II outside 2 SD
40.0% of class III outside 2SD

54.2% of class I outside 1SD
60.7% of class II outside 1 SD
60.0% of class III outside 1SD

TABLE 5 Oneway ANOVA - Bolton anterior and overall ratio for malocclusion groups demonstrating no statistically significant (P>0.05) difference between class I, class II and class III

	N	ANTERIOR RATIO			OVERALL RATIO		
		MEAN	SD	P VALUE	MEAN	SD	P VALUE
CLASS I	129	78.6	4.8	0.361	90.5	4.2	0.179
CLASS II	79	78.1	5.1	0.361	91.4	4.0	0.179
CLASS III	30	79.5	3.6	0.361	92.1	5.7	0.179

TABLE 6 Comparison between anterior and overall ratios among different malocclusion groups and Bolton standards – one sample "t" test demonstrating statistically significant (P<0.05) difference between Bolton's and class I and class III mean anterior ratio.

	N	ANTERIOR RATIO			OVERALL RATIO		
		MEAN	SD	P VALUE	MEAN	SD	P VALUE
BOLTON	55	77.2	1.65		91.3	1.91	
CLASS I	129	78.6	4.8	**0.001**	90.5	4.2	0.063
CLASS II	79	78.1	5.1	O.912	91.4	4.0	0.789
CLASSIII	30	79.5	3.6	**0.001**	92.1	5.7	0.486

CHART 1 The percentage distribution of class I anterior tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

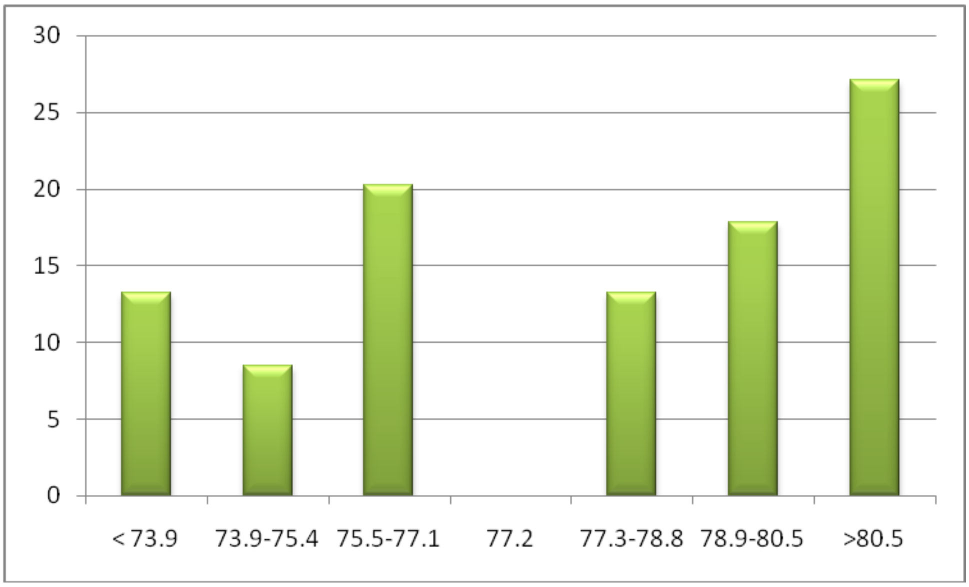


CHART 2 The percentage distribution of class II anterior tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

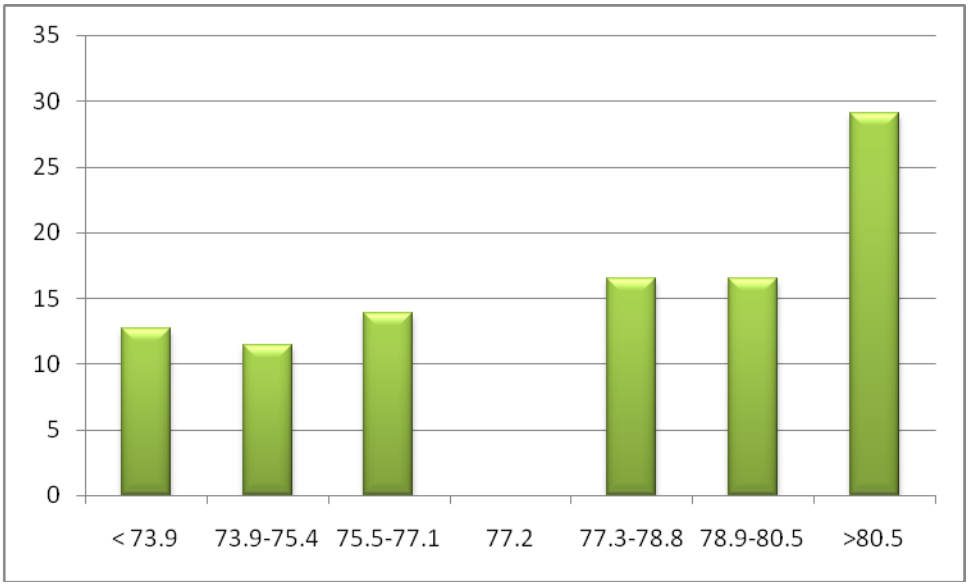


CHART 3 The percentage distribution of class III anterior tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

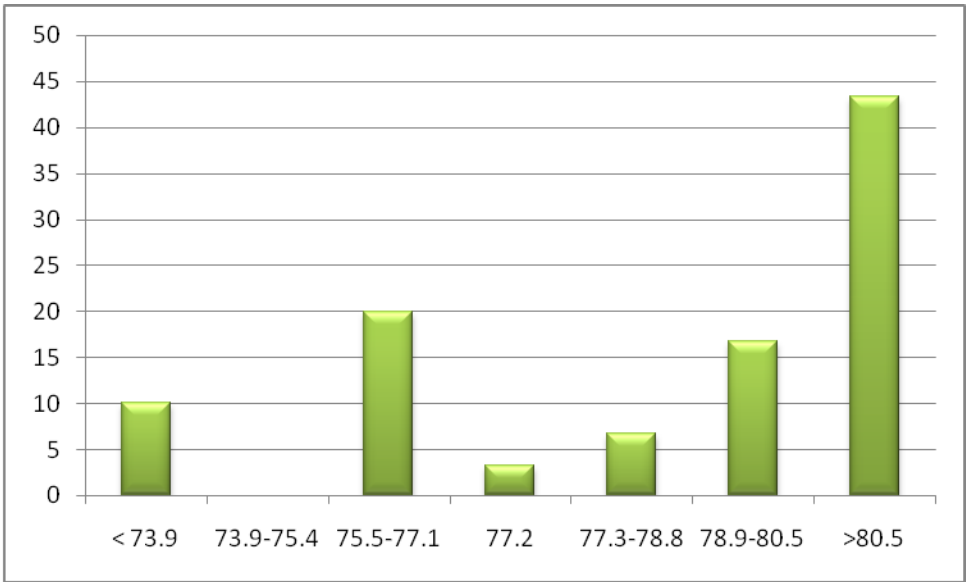


CHART 4 The percentage distribution of class I overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

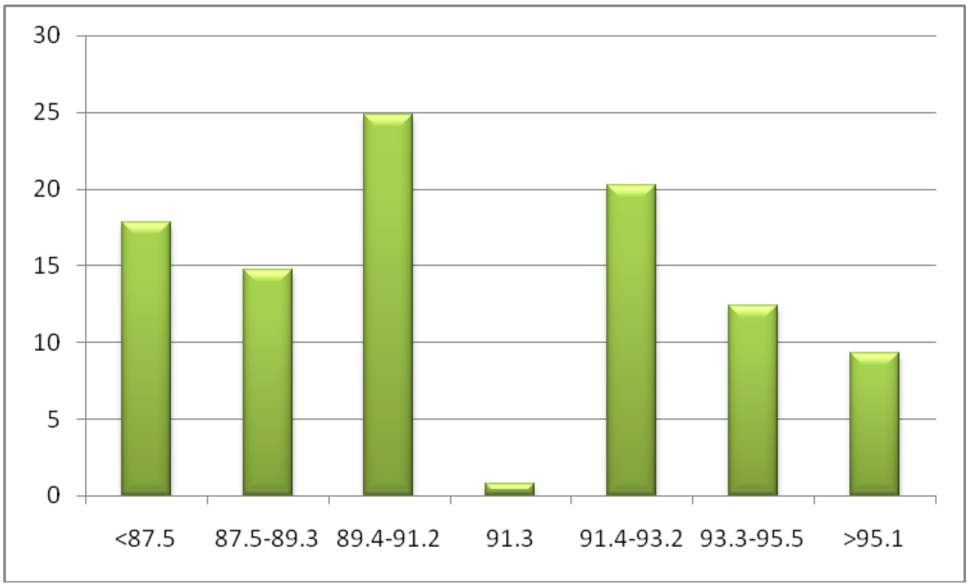


CHART 5 The percentage distribution of class II overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

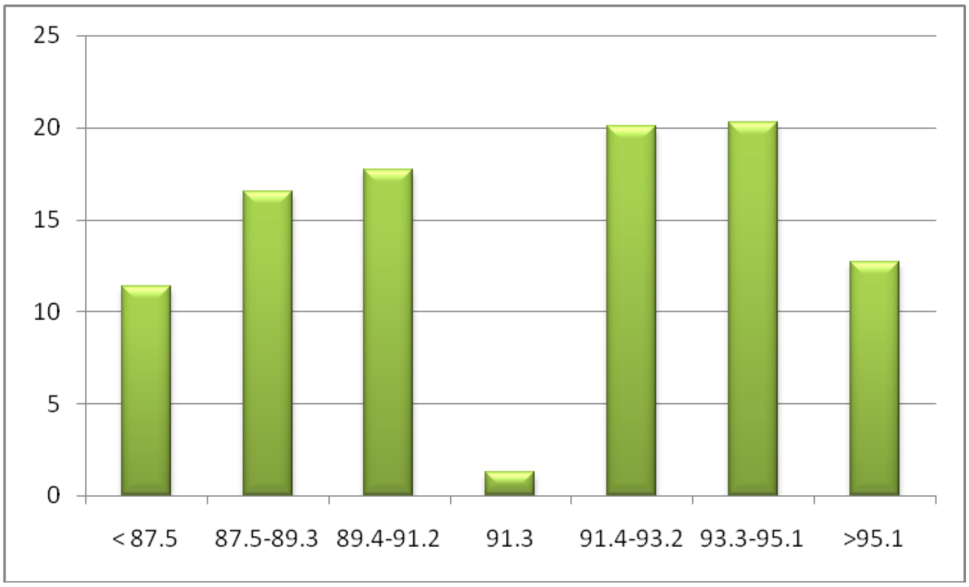


CHART 6 The percentage distribution of class III overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean

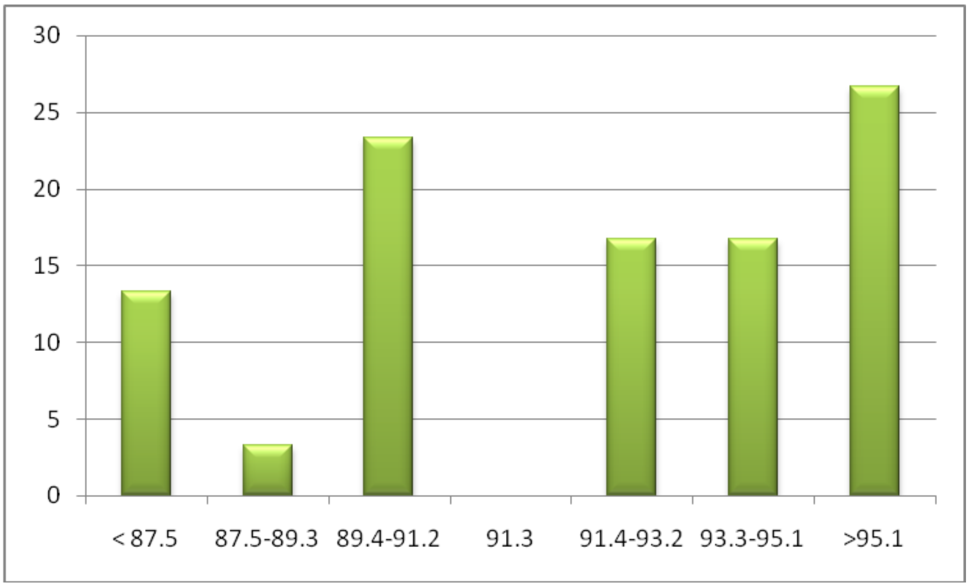


CHART 7 The percentage distribution of overall tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean in Chennai population

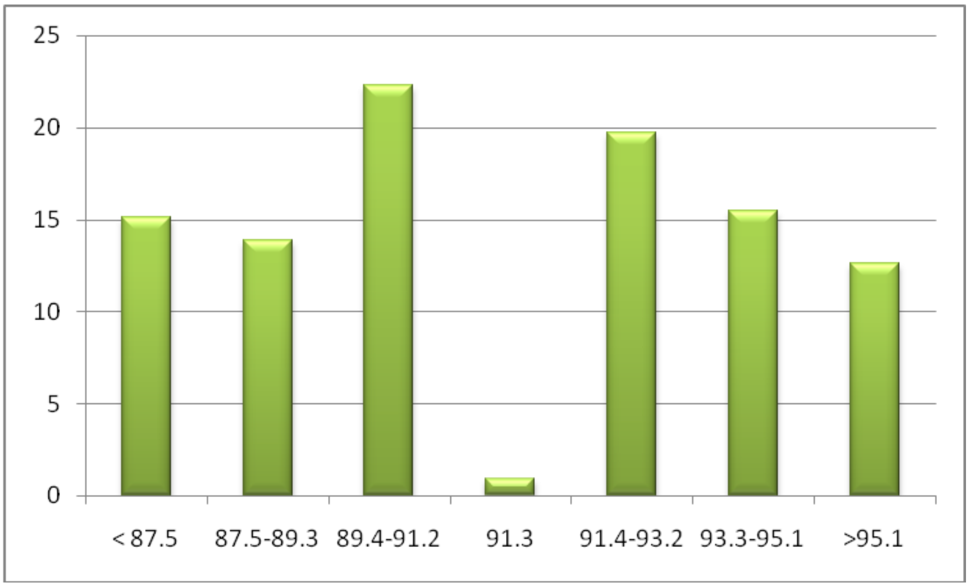


CHART 8 The percentage distribution of anterior tooth size discrepancies outside 1 or 2 standard deviations (SDs) from Bolton's mean in Chennai population.

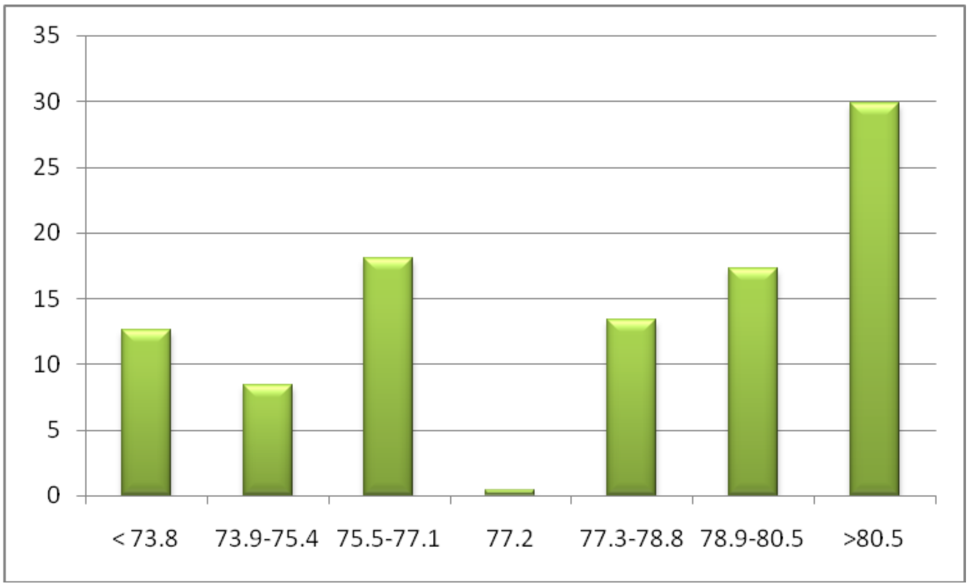
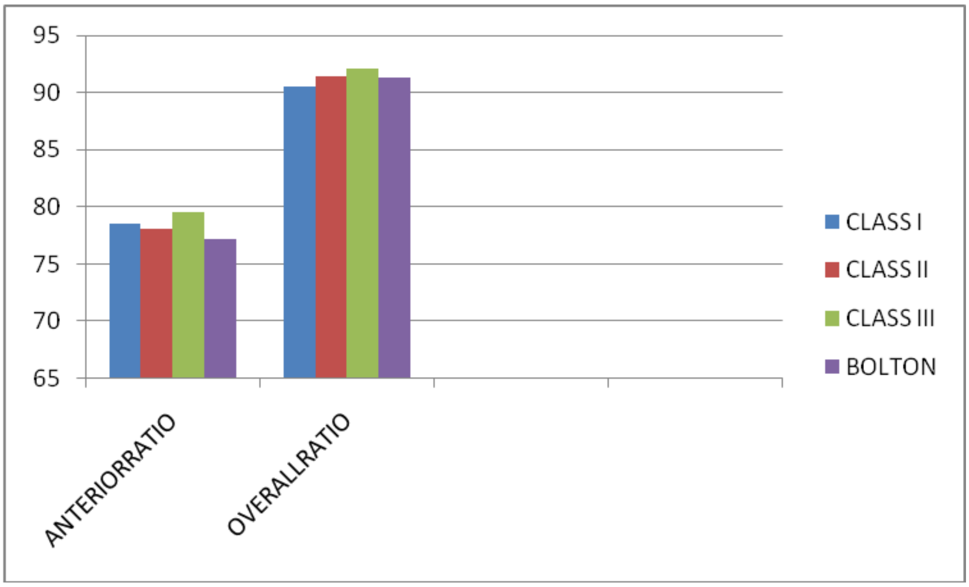


Chart 9 Comparison between anterior and overall ratios among different malocclusion groups and Bolton standards



DISCUSSION

The clinician should be familiar with discrepancies in tooth size at the initial diagnosis and treatment planning stages if excellence in orthodontic finishing is to be achieved. Tooth size discrepancies are considered an important variable especially in the anterior segment. Lavelle[34] stated that although tooth size and proportion have an important role in malocclusion, the study of tooth dimensions has received scant attention by orthodontists.

It has been commonly accepted that the mesiodistal crown diameters of the upper and lower teeth should match each other for a balanced occlusion. Significant higher overall ratios can be explained by relatively larger mandibular or smaller maxillary arch segments, and thus there might be an association between malocclusion and tooth size. In other words, tooth size discrepancies between maxillary and mandibular teeth may be an important factor in the cause of malocclusions.

Genetic influences have been considered important in the determination of tooth dimensions, and the first reports were related to clinical observations within families. Studies on twins, however, helped in understanding the genetic contribution of tooth size in that a greater tooth size correlation was found in monozygotic twins. Other investigators de-emphasized the genetic contribution and described the determination of tooth size as multifactorial, with the environment playing an important role. Teratogenic and nutritional factors have been associated with the mechanism of tooth formation. Space limitations and nutrition have been described as important in the development of a healthy tooth germ and have been related to alterations in number, shape, and form of permanent teeth. Although it is widely accepted that both genetic and environmental variables affect tooth development, it is virtually impossible to identify and describe the role each of these variables play in the determination of tooth size.

The first concerns expressed in dental literature related to tooth size date back to the 1920s. In different publications, Gilpatric, Young, cited by Bolton, and Stanton stated that there should be a proportion between upper and lower teeth. Gilpatric and later Stanton studied 2000 individuals and found that the upper teeth should be 8- to 12- mm larger than the lower dentition and that a value greater than 8- to 12-mm would result in an excessive overbite. Several studies were published describing the importance of a correct tooth size proportion between the upper and lower arches.

After observing 200 cases, Neff[45] developed a proportion for the width dimension of the teeth called the *anterior coefficient.* He found that an optimal overbite was represented when maxillary mesiodistal sum divided by the mandibular mesiodistal sum resulted in a ratio of 1.20 to 1.22. Lundstrom[37] studied the relationship between the mandibular and the maxillary anterior sum and named it the *anterior index.*

Bolton[17] evaluated 55 cases with ‘‘excellent’’ occlusion. After considering tooth sizes from first molar to first molar in the maxillary and mandibular arches, Bolton established an ideal anterior ratio with a mean value of 77.2% and standard deviation (SD) of 1.65% and an ideal over all ratio with a mean value of 91.3% and standard deviation(SD) of 1.91% using the below calculation,

Bolton's Overall ratio =

Sum of mandibular "12"-first molar) x100

Sum of maxillary "12"

Bolton's Anterior ratio =

Sum of mandibular " 6" teeth x100

Sum of maxillary "6" teeth

The author concluded that it would be very difficult to obtain an excellent occlusion in the finishing phase of treatment without a correct mesiodistal tooth size ratio. Bolton's articles had a profound impact because most tooth size studies since his publication have used the Bolton tooth size discrepancy analysis to diagnose tooth size discrepancies.

In more recent articles, other variables such as incisor inclinations, upper-incisor thickness, and arch form have been described as important to consider in achieving optimal occlusion relationships. Efforts have been made to adapt the Bolton analysis to these variations. Several authors proposed new methods to study tooth size discrepancies. However, these proposals need to be tested in clinical studies and, for now, the Bolton analysis prevails as an efficacious clinical tool for appraising various relationships of upper to lower dentitions. Orthodontists should be concerned with tooth size discrepancies because of the high incidence in orthodontic patient populations.

In order to predict the occlusal relationships at the end of orthodontic treatment, a number of studies have been carried out. Many investigators have attempted to quantify inter-arch tooth size discrepancies, but none are as useful or as well accepted as Bolton's analysis. The present study was carried out on Chennai subjects. Both the skeletal classification, according to ANB, and Angle's dental classification were used for determination of the groups.

ANB is affected by several factors in the craniofacial structures (Oktay[47], 1991; Hurmerinta[29] *et al.*, 1997), and thus floating norms have been introduced for ANB angle (Järvinen, 1986). In order to overcome the limitations of this angle, the selection criteria in the present study included Class II patients with ANB angle greater than 5 degrees and Class III patients with an ANB less than 0 degrees similar to the studies of Laino[32] *et al.* (2003) and Uysal[73] *et al.* (2005).

Needle-pointed orthodontic dividers are commonly used to determine the greatest mesiodistal diameter of the teeth. Digital callipers are also used to measure the teeth to the nearest 0.1 or 0.01 mm. In recent years, new techniques and devices have been developed in order to achieve more accurate and reliable tooth measurements (Yen[78], 1991; Schirmer and Wiltshire[60], 1997; Mok and Cooke[41], 1998; Nie and Lin[44], 1999; Tomasetti[69] *et al.*, 2001; Othman and Harradine[48], 2006). All tooth measurements in this study were carried out using digital vernier caliper device., allowing the greatest mesiodistal diameters of the teeth to be easily measured, even if crowding is present.

TEETH SIZE DISCREPANCIES AND GENDER

As in many other human attributes, teeth vary in size between males and females. Gender differences have been reported in the literature and may have clinical relevance. According to Seipel[61], cited by Lavelle[34], there are fewer gender differences in the primary dentition than in the permanent dentition. Male teeth are generally recognized to be larger than female teeth. In both the primary and permanent dentitions, the upper canines and upper central incisors show the greatest gender differences, whereas the upper lateral incisor and lower central incisor are the most homogenous.

There is lack of agreement regarding gender differences in relation to the tooth size proportion between upper and lower anteriors. Moorrees[42] *et al.* (1957) showed gender differences in overall ratio. Lavelle[48] (1972) reported relatively larger overall and anterior ratios in males compared with white, black, and mongoloid female populations. Richardson and Malhotra[53](1975) found that the teeth of black North American males were larger than those of females for each type of tooth in both arches, but there were no differences in anterior or posterior inter-arch tooth-size proportions. Crosby and Alexander[19] (1989) did not differentiate between genders and did not mention whether there was sexual dimorphism for tooth size ratios in their sample. However, these sex differences were small, all being less than 1%. Nie and Lin[44] (1999) found no difference between the genders for the three tooth size ratios. Smith[64] *et al.* (2000) found larger overall and posterior ratios in black, Hispanic, and white males. Al-Tamimi and Hashim[5](2005) also found no sexual dichotomy in Bolton ratios in a relatively small sample of 65 Saudi subjects. Uysal and Sarı[72] (2005) found statistically significant gender difference only in overall ratio. Santoro[57] *et al.* (2000), Ta[71] *et al.* (2001), Basaran[12] *et al.* (2006), Endo[23] *et al.* (2007), and Al-Omari *et al.* (2008) on the other hand observed no sexual dimorphism in overall and anterior ratios.. The results of the present study showed no sexual dimorphism in overall and anterior ratios (P>0.05).

THE PREVALENCE OF TOOTH-SIZE DISCREPANCIES

Orthodontists should be concerned with tooth size discrepancies because of the high incidence in orthodontic patient populations. Bolton reported tooth size discrepancies greater than ± SD in 29% of the patients studied in his private practice, and Richardson and Malhotra[53](1975) reported similar discrepancies in 33.7% of their patients. Originally, Bolton suggested that a ratio greater than 1 SD from his reported mean values indicated a need for diagnostic consideration. Crosby and Alexander[19] stated that a tooth size discrepancy had to be greater than ±2 SD, eg, two to three mm of deviation, to influence the course of orthodontic treatment. In studies involving 109 individuals, 22.9% showed anterior ratios that significantly deviated from the Bolton analysis mean (greater than ±2 SD). Freeman[24] et al found that 30% of 157 subjects studied had an anterior tooth size discrepancy ratio greater than ±2 SD from the Bolton mean. In a more recent study, Santoro[58] et al(2003) reinforced the findings of Crosby and Alexander[19] observing that 28% of 54 Dominican

Americans presented a discrepancy greater than ±2 SD. Araujo and Souki[7](2003) found similar prevalence values to Freeman. Bernabe[13] et al. studied TSD in 200 Peruvian adolescents with untreated occlusions. Importantly, this sample was selected from a school, not from an orthodontic clinic, so may not have been representative of patients undergoing orthodontic treatment

An anterior ratio below 73.9 or above 80.5 and a total ratio below 87.5 or above 95.1 would be considered clinically significant. In the present study, 42.4% of the sample had anterior tooth-width ratios greater than 2 SD from Bolton's mean (29.8% greater than + 2 SD and 12.6% greater than - 2 SD). 27.7% had overall tooth-width ratios greater than 2 SD from Bolton's mean (12.6% more than +2 SD and 15.1% greater than -2 SD). Among the 3 malocclusion groups Class III malocclusion group showed greater prevalence of tooth size discrepancies(anterior ratio-53.3% and overall ratio-40%) compared to class II(anterior ratio-41.8% and overall ratio-24%) and class I(anterior ratio-40.3% and overall ratio-27.1) greater than 2 standard deviation. The present study showed the tendency of mandibular tooth size excess in more class III malocclusion than the other classes. This indicated that it might be reasonable for the orthodontists to do interproximal stripping or tooth extraction in the mandibular dentition for class III malocclusion. These results suggested that the Bolton analysis is important and should be considered when diagnosing, planning and predicting prognosis in clinical orthodontics.

TOOTH-SIZE DISCREPANCIES IN DIFFERENT CLASSES OF MALOCCLUSION

Lavelle[48] showed that tooth sizes of Class III were the smallest among the 3 occlusion categories (ie, ClassI, Class II and Class III) for maxillary teeth; they were the greatest for mandibular teeth. This possibly indicated that tooth size ratios of mandibular teeth divided by maxillary teeth in Class III may be the greatest among different malocclusion types. However, these ratios were not compared in his study. His result was only a kind of descriptive statistical result, which stated the mean size of each tooth of male patients for each malocclusion type and described a pattern of contrast. Sperry[65] et al. demonstrated that the frequency of relative mandibular tooth size excess (for the overall ratio) was greater in cases of Angles Class III. Crosby and Alexander[19] studied the prevalence of TSD among different malocclusion groups with between 20 and 30 subjects in each group. For the anterior ratio, 16.7% of the Class I patients had a significant discrepancy, whereas this figure was 23.4% in the Class II division 1 group. This difference is highlighted because it might be considered potentially significant, but in fact there were no statistically significant differences in the prevalence of TSD among the malocclusion groups. Nie and Lin[44] conducted a study of this aspect of TSD in a sample of 360 cases. A significant difference was found for all the ratios between the malocclusion groups, showing that the anterior, posterior and overall ratios were all greatest in Class III and lowest in Class II. Araujo and Souki[7] concluded that individuals with Angle Class III malocclusions had a significantly greater prevalence of TSD than did those with Class I individuals who, in turn, had a greater prevalence than those with Class II malocclusion. This statistically significant trend to larger ratios in Class III patients was also reported by Ta et al[71]. in a southern Chinese population and by Alkofide and Hashim[4] in a Saudi population. Liano[32] et al. concluded that there was no association between TSD and the different malocclusion groups, but with only 13 subjects in their Class III group, statistically significant differences were improbable. The study by Uysal[73] et al. was interesting in that there were no differences between malocclusion types, but all malocclusion groups had significantly higher average ratios than the group of 150 untreated normal occlusions. This last group is exceptionally large, but is a rare feature of studies investigating TSD. Cua-Benward[20] et al studied the prevalence of missing teeth in different malocclusion groups, relating their findings to Moss's functional matrix concept. They found a greater prevalence of tooth deformities in the maxilla in Class III individuals, whereas they found more tooth deformities in the mandible in Class II individuals. Sassouni was the first to report that individuals with a Class III facial type and deficient maxillary growth showed a greater prevalence of alterations in shape of the anterior teeth as well as a greater incidence of agenesis.

The present study found no significant difference between class I, class II and class III malocclusion groups. The difference in the results between this study and the other investigations might be attributed to the sample size, method of analysis, sample size, and large standard deviation found in this study.

ANTERIOR AND OVERALL RATIOS AMONG DIFFERENT MALOCCLUSION GROUPS AND BOLTON STANDARDS

In the anterior ratio, a statistically significant difference was found between the Bolton standard and the Class I and Class III malocclusion group. In the overall ratio, there was no statistically significant differences found between the Bolton standard and the Class I, Class II and Class III malocclusion groups. For both overall and anterior ratio in the present study, the mean and standard deviation was larger than in Bolton’s study (1958). This finding is consistent with the results of Nie and Lin[44](1999), Smith[64] et al(2000), and Al-Omariet al(2008). Crosby and Alexander[19](1989), Freeman[24] et al and Santoro[57] et al(2000) fond that the mean in their studies and those of Bolton's study were nearly identical although the ranges and standard deviation were significantly larger. The probable reason for these findings in the present study may be the types of population that constituted the study samples.

Lastly, evaluating tooth-size discrepancies is only part of the diagnostic orthodontic treatment-planning process. Other factors, including soft tissue, skeletal, and other dental evaluation factors, also significantly contribute to developing a logical and cogent treatment plan. Tooth-size discrepancies should be evaluated and addressed while simultaneously considering other treatment issues. The final treatment plan and outcome are best evaluated as the sum of the constituent parts, not the individual parts themselves.

SUMMARY AND CONCLUSION

An observational and cross sectional study was done to determine whether there is a difference in intermaxillary tooth size discrepancies among the malocclusion groups and to determine the percentage of tooth size discrepancies outside 1 or 2 standard deviations from Bolton’s inter arch tooth size ratio.

The study two hundred and thirty eight study models randomly selected from archives of the department of orthodontics, Tamil Nadu Government Dental College and Hospital, Chennai, Tamil Nadu. The samples were divided into three groups based on Angle’s classification of malocclusion – class I, class II Div I, and class III, coinciding with skeletal relationship, which was based on the steiner’s ANB angle: class I 0<ANB <5; class II ANB >5 and class III ANB <o. Each of these groups was again divided into two groups- males and females.

The Bolton’s anterior and overall ratio was calculated for each group. The values were then compared for any possible gender difference and also among each group and with that of Bolton’s normal value.

The study concludes that

1. There were no significant differences in the tooth size discrepancy between male and female.
2. The percentage of subjects with a deviation of more than 1 standard deviation for anterior and overall ratio was 68 and 57.1 respectively.
3. The percentage of subjects with a deviation of more than 2 standard deviation for anterior and overall ratio was 42.4 and 27.7 respectively.
4. Class III malocclusion group showed greater prevalence of tooth size discrepancies greater than 2 standard deviation compared to class II and class I.
5. There were no statistically significant differences in the Bolton anterior and overall ratios between the different malocclusion groups - class I, class II and class III.

6. The anterior ratio of class I and class III in the present study was significantly larger than the Bolton's normal value for anterior ratio.

Recent technological advances have allowed the introduction of digital callipers, which can be linked to computers for rapid calculation of the Bolton's anterior and overall ratio and this computer program can virtually eliminate measurement transfer and calculation errors, compared with analysis that requires dividers, rulers and calculators. Few computerised methods like Quick Ceph, HATS, and OrthoCad needs special mention here.

BIBLIOGRAPHY

1. Agenter et al Influence of tooth crown size on malocclusion Am J Orthod Dentofacial orthop 2009;136
2. Akcam et al Evaluation of 3-dimensional tooth crown size in cleft lip and palate patients Am J Orthod Dentofacial orthop 2008; 134:85
3. Akyalcin S, Dogan S, Dincer B, Erdinc AM, Oncag G. Bolton tooth size discrepancies in skeletal Class I individuals presenting with different dental Angle classifications. Angle Orthod 2006; 76:637-43
4. Alkofi de E , Hashim H 2002 Intermaxillary tooth-size discrepancy among different malocclusion Classes: a comparative study . Journal of Clinical Pediatric Dentistry 24 : 383 – 387
5. Al-Tamimi T, Hashim HA Bolton tooth-size ratio revisited. World J Orthod 2005; 6(3): 289–95
6. Andrews L F 1972 The six keys to normal occlusion . American Journal of Orthodontics 62 : 296 – 309

7. Araujo E, Souki M 2003 Bolton anterior tooth size discrepancies among different malocclusion groups. Angle Orthodontist 73: 307–313

8. Arkutu et al. Bolton’s discrepancy : which way is better? British Orthodontic Conference 2004

9. Arya B S, Savara B S, Thomas D, Clarkson Q 1974 Relation of sex and occlusion to mesiodistal tooth size. American Journal of Orthodontics 66: 479-486

10. Ballard ML. Asymmetry in tooth size: a factor in the etiology, diagnosis and treatment of malocclusion. Angle Orthod 1944; 14: 67–71.

11. Ballard ML. And Wylie, W.L, Mixed dentition case analysis Amer. J. of ortho. And oral surgery 1947

12. Basaran G, Selek M, Hamamcı O, Akkus Z 2006 Intermaxillary Bolton tooth size discrepancies among different malocclusion groups. Angle Orthodontist 76:26–30

13. Bernabe E, Major PW, Flores-Mir C. Tooth-width ratio discrepancies in a sample of Peruvian adolescents. Am J Orthod Dentofacial Orthop 2004;125:361-5.

14. Bernabe et al . Occlusal indicators of crowding. Am J Orthod and Dentof Orthop 2005

15. Bishara et al. Changes in tooth size Am J Orthod Dentofacial Orthop 1995

16. Black GV . Descriptive anatomy of human teeth, 4th edition, Philadelphia: S.S White, 1902

17. Bolton W A 1958 Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthodontist 28: 113–130

18. Bolton W A 1962 The clinical application of a tooth size analysis. American Journal of Orthodontics 48: 504–529

19. Crosby DR, Alexander C G 1989 The occurrence of tooth size discrepancies among different malocclusion groups. American Journal of Orthodontics and Dentofacial Orthopedics 95: 457–461

20. Cua-Benward GB, Dibaj S, Ghassemi B. The prevalence of congenitally missing teeth in Class I, II, III malocclusions. J Clin Pediatr Dent 1992;17:15-7.

21. Doris JM, Bernard BW, Kuftinec MM, Stom D. A biometric study of tooth size and dental crowding. *Am J Ortho*. 1981;79:326–336.

22. Endo T, Shundo I, Abe R, Ishida K, Yoshino S, Shimooka S 2007 Applicability of Bolton's tooth size ratios to a Japanese orthodontic population. Odontology 95: 57–60

23. Endo et ai Effects of premolar extractions on Bolton overall ratios and tooth-size discrepancies in a Japanese orthodontic population Amj ortho 2010

24. Freeman J E, Maskeroni A J, Lorton L 1996 Frequency of Bolton tooth-size discrepancies among orthodontic patients. American Journal of Orthodontics and Dentofacial Orthopedics 110: 24–27

25. Halazonetis et al. Bolton's ratio studied with the use of spreadsheets. Am J Orthod and Dentof Orthop 1996

26. Heusdens M, Dermaut L, Verbeek R. The effect of tooth size discrepancy on occlusion: an experimental study. Am J Orthod Dentofacial Orthop 2000; 117: 184–91.

27. Ho CTC, Freer TJ. A computerized tooth width analysis. J Clin Orthod 1999; 33: 498–503.

28. Houston W J B 1983 The analysis of errors in orthodontic measurements. American Journal of Orthodontics 83: 382–390.

29. Hurmerinta K, Rahkamo A, Haavikko K 1997 Comparison between cephalometric classification methods for sagittal jaw relationships. European Journal of Oral Sciences 105: 221–227

30. Järvinen S 1986 Floating norms for the ANB angle as guidance for clinical considerations. American Journal of Orthodontics and Dentofacial Orthopedics 90: 383–387.

31. Kayalioglu et al. Tooth size ratio requiring four first premolar extractions. Am J Orthod and Dentof Orthop 2005.

32. Laino A, Quaremba G, Paduana S, Stanzione S 2003 Prevalence of tooth-size discrepancy among different malocclusion groups. Progress in Orthodontics 4: 37–44

33. Lavelle C L B 1972 Maxillary and mandibular tooth size in different racial groups and in different occlusal categories. American Journal of Orthodontics 61: 29–37

34. Lavelle CL. Variations in the secular changes in the teeth and dental arches. *Angle Orthod.* 1972;43:412–421.

35. Lee et al. Cluster analysis of tooth size Am J Ortho and Dento Orthop 2007

36. Lestrel et al. A quantitative approach to measurement of crowding. Am J Orthod and Dentof Orthop 2003

37. Lundstro¨m A. Intermaxillary tooth width ratio and tooth alignment and occlusion. *Acta Odontol Scand.* 1954;12:265–292.

38. Lysell L, Myrberg N 1982 Mesiodistal tooth size in the deciduous and permanent dentitions. European Journal of Orthodontics 4: 113–122

39. McLaughlin R P, Bennet J C, Trevesi H J systemised orthodontic treatment mechanics. Mosby, St. Louis, p.285s

40. Merz ML, Isaacson RJ, Germane N, Rubenstein LK. Tooth diameters and arch perimeters in a black and a white population. Am J Orthod Dentofacial Orthop 1991;100:53-8.

41. Mok K H Y, Cooke M S 1998 Space analysis: a comparison between sonic digitization (DigiGraph Workstation) and the digital caliper. European Journal of Orthodontics 20: 653–661.

42. Moorrees C F A, Thomsen S O, Jensen E, Yen P K J 1957 Mesiodistal crown diameters of the deciduous and permanent teeth in individuals. Journal of Dental Research 36: 39–47

43. Mullen et al Accuracy of space analysis with plaster and e models Am J Orthod and Dentof Orthop 2007

44. Nie Q, Lin J 1999 Comparison of intermaxillary tooth size discrepancies among different malocclusion groups. American Journal of Orthodontics and Dentofacial Orthopedics 116: 539–544

45. Neff CW. Tailored occlusion with the anterior coefficient. *Am J Ortho.* 1949;35:309–313.

46. Neff CW. The size relationship between the maxillary and mandibular anterior segments of the dental arch. Angle Orthod 1957;27:138-47.

47. Oktay H 1991 A comparison of ANB, Wits, AF-BF, and APDI measurements. American Journal of Orthodontics and Dentofacial Orthopedics 99: 122–128

48. Othman S A, Harradine N W T 2006 Tooth-size discrepancy and Bolton's ratios: a literature review. Journal of Orthodontics 33: 45–51

49. Othman S A, Harradine N W T 2007 Tooth size discrepancies in an orthodontic population. Angle Orthodontist 77: 668–674

50. Paredes V, Gandia J L, Cibrian R 2006 Do Bolton's ratios apply to a Spanish population? American Journal of Orthodontics and Dentofacial Orthopedics 129: 428–430.

51. Puri et al. Biometric study of tooth size in normal, crowded and spaced dentition Am J Orthod and Dentof Orthop 2003

52. Qiong N, Jiuxiang L. Comparison of intermaxillary tooth size discrepancies among different malocclusion groups. Am J Orthod Dentofacial Orthop 1999;116:539-44.

53. Richardson ER, Malhotra SK. Mesiodistal crown dimension of the permanent dentition of American Negroes. Am J Orthod 1975;68:157-64.

54. Rudolph DJ, Dominguez PD, Ahn K, Thinh T. The use of tooth thickness in predicting intermaxillary tooth-size discrepancies. Angle Orthod 1998; 68: 133 8.

55. Saatci P, Yukay F. The effect of premolar extractions on tooth size discrepancy. Am J Orthod Dentofacial Orthop 1997; 111: 428–34.

56. Sameshima GT. Bolton tooth size variation among four ethnic groups. Eur J Orthod 2006;45:234-50

57. Santoro M, Ayoub M E, Pardi V A, Cangialosi T J 2000 Mesiodistal crown dimensions and tooth size discrepancy of the permanent dentition of Dominican Americans. Angle Orthodontist 70: 303–307

58. Santoro et al. Comparison of digital and plaster models. Am J Orthod and Dentof Orthop 2003

59. Sassouni V. A classification of skeletal facial types. *Am J Ortho.* 1969;55:109–123.

60. Schirmer U R, Wiltshire W A 1997 Manual and computer-aided space analysis: a comparative study. American Journal of Orthodontics and Dentofacial Orthopedics 112: 676–680

61. Seipel CM. Variation in tooth position. A metric study of variation and adaptation in the deciduous and permanent dentitions. Swed Dent J 1946;39(Supp.):1-176.

62. Shellhart W C, Lange W, Kluemper G T, Hicks P, Kaplan A 1995 Reliability of the Bolton tooth-size analysis when applied to crowded dentitions. Angle Orthodontist 65: 327–334

63. Sheridan J J 2000 The reader's corner. Journal of Clinical Orthodontics 34: 593–597

64. Smith S S, Buschang P H, Watanabe E 2000 Interarch size relationships of three populations: does Bolton's analyses apply? American Journal of Orthodontics and Dentofacial Orthopedics 117: 169–174.

65. Sperry T P, Worms F W, Isaacson R J, Speidel T M 1977 Tooth-size discrepancy in mandibular prognathism. American Journal of Orthodontics 72: 183–190
66. Steadman, S. R.: Predetermining the Overbite and Overjet, Angle Orthodontist 19: 101-105, 1949.
67. Stifter J 1958 A study of Pont's, Howes', Rees', Neff's and Bolton's analyses on Class I adult dentitions. Angle Orthodontist 28: 215–225.
68. Ta T A, Ling J Y K, Hägg U 2001 Tooth-size discrepancies among different occlusion groups of southern Chinese children. American Journal of Orthodontics and Dentofacial Orthopedics 120: 556–558
69. Tomasetti J J, Taloumis L J, Denny J M, Fisher J R 2001 A comparison of 3 computerized Bolton tooth size analyses with a commonly used method. Angle Orthodontist 71: 351–357
70. Tong H, Chen D, Xu L, Liu P. The effect of premolar extractions on tooth size discrepancies. Angle Orthod 2004; 74: 508–11

71. Tu An Ta et al. Tooth size discrepancies of southern Chinese population. Am J Orthod and Dentof Orthop 2001

72. Uysal T, Sarı Z 2005 Intermaxillary tooth size discrepancy and mesiodistal crown dimensions for a Turkish population. American Journal of Orthodontics and Dentofacial Orthopedics 128: 226–230

73. Uysal T, Sarı Z, Başçiftçi F A, Memili B 2005 Intermaxillary tooth size discrepancy and malocclusion: is there a relation? Angle Orthodontist 75: 208–213

74. Uysal et al New regression equation for mixed dentition arch analysis Amj of ortho and dent orthop 2009

75. Warren et al. Tooth size and arch length relationship in the deciduous dentition. Am J Orthod and Dentof Orthop 2003

76. White L W 1982 The clinical use of occlusograms. Journal of Clinical Orthodontics 16: 92–103

77. Xia Z, Wu X Y 1983 The application of dentocclusal measurement in malocclusion. Stomatology 3: 126–127

78. Yen C H 1991 Computer-aided space analysis. Journal of Clinical Orthodontics 25: 236–238

79. Yoshihara et al. Effect of serial extraction on crowding. Am J Orthod and Dentof Orthop 1999

80. Zilberman O, Huggare JAV, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and 3-dimensional virtual orthodontic models. Angle Orthod 2003; 73: 301–6.