CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Good occlusion is produced by teeth that are proportional in size. If large upper teeth occlude with small lower teeth, it would be almost impossible to achieve ideal occlusion. Although the natural teeth match well in most individuals, approximately five percent of the population have some amount of disproportion among sizes of individual teeth. This is defined as tooth size discrepancy (Proffit and Fields, 2000).

The concept of ideal intercuspation assumes a strict relationship between tooth size and the size of maxillary and mandibular arches. Specific dimensional relationships must exist between the maxillary and mandibular teeth to ensure proper interdigitation, overbite, and overjet. Inter-arch tooth size discrepancies requires either removal or addition of tooth structure to resolve the problem during orthodontic treatment. It is important to determine the amount and location of tooth-size discrepancies before starting treatment (Uysal *et al.*, 2005; Basaran *et al.*, 2006).

Bolton (1958), developed two equations to analyse the mesio-distal tooth size ratio between permanent maxillary and mandibular teeth. Anterior Bolton ratio was calculated for six anterior teeth (canine to canine) and the overall Bolton ratio was calculated for the anterior and posterior teeth, full arch excluding second and third molars. The ratios are expressed in a percentage relationship of mandibular teeth to maxillary teeth. Bolton's study in Washington, USA, comprised of 55 Caucasian subjects with excellent occlusion. By comparing the results of the two ratios, space deficiency or areas of excessive space were identified (Santoro *et al.*, 2000). Bolton's ratios are a useful diagnostic tool used in clinical orthodontics to achieve ideal occlusion of the dentition for diagnosis and treatment planning. Studies have been undertaken to determine occlusion based on ethnic, racial and gender differences that may exist amongst individuals (Richardson and Malhotra, 1975; Smith, Buschang and Watanabe, 2000; Paredes, Gandia and Cibrian, 2006a; Uysal, Basciftci and Goyenc, 2009).

The purpose of this study was to investigate whether Bolton's ratios which were formulated using a Caucasian sample would be applicable to a select sample of South African Blacks at the Department of Orthodontics, Medunsa Oral Health Centre, University of Limpopo.

1.2 RESEARCH OBJECTIVES

The objectives of this study were to:-

1. Establish the mesio-distal tooth width ratios of maxillary to mandibular permanent teeth in a select sample of South African Blacks.
2. Compare the tooth width ratios of a select sample of South African Blacks to the ratios available from Bolton's ratios and propose alternative ratios if Bolton's analyses are found to be inapplicable.
3. Establish whether there are gender differences with regard to the ratios obtained.

1.3 NULL HYPOTHESIS

1. Anterior tooth width ratios for a select group of South African Blacks will not differ from Bolton’s ratio of 77.2%.
2. Overall tooth width ratios for a select group of South African Blacks will not differ from Bolton’s ratio of 91.3%.
3. Anterior and overall tooth width ratios will not differ between males and females for the select group of South African Blacks.

CHAPTER 2: LITERATURE REVIEW

2.1 OCCLUSION

The publication of Angle's classification of malocclusion in the 1890's was an important step in the development of Orthodontics because it not only subdivided major types of malocclusion but also included the first clear and simple definition of normal occlusion in the natural dentition. Angle (1899) postulated that the maxillary first molars were the key to occlusion and that the maxillary and mandibular molars should be related so that the mesiobuccal cusp of the maxillary molar occludes in the buccal groove of the mandibular molar. If this molar relationship existed and the teeth were arranged on a smoothly curving line of occlusion, then normal occlusion would result.

Normal occlusion and Class I malocclusion share the same molar relationship but differ in the arrangement of the teeth relative to the line of occlusion (Angle, 1899). The line of occlusion may or may not be correct in a Class II and Class III malocclusion (Neff, 1949). For ideal occlusion, the maxillary and mandibular teeth must be proportional in size. An anomaly in the size of the maxillary lateral incisors is the most common cause of tooth size discrepancy, but variations in premolars or other teeth may be present. Occasionally, all the maxillary teeth may be too large or too small to fit properly with the mandibular teeth (Bolton, 1958). Andrews (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. Andrews' (1972) "Six Keys to Normal Occlusion" are useful in achieving functional goals.

In normal occlusal relationships and good incisor position tooth size discrepancies are often the cause of rotations, space formations, crowding and incorrect intercuspation. Disharmony between the width of the maxillary and mandibular teeth can be improved by extractions, interdental stripping, and in extreme cases, by increasing the mesio-distal tooth size. A disproportion between maxillary and mandibular tooth size depends on the localisation of excessive tooth material. Excessive tooth material in the maxillary arch can present with an increased overbite, increased overjet, crowding in the maxillary arch, spacing in the mandibular arch, linguoversion of the maxillary incisors and labioversion of the mandibular incisors. Excessive tooth material in the mandibular arch can present with a reduced overbite, a reduced overjet, crowding in the mandibular arch, spacing in the maxillary arch, labioversion of the maxillary incisors and linguoversion of the mandibular incisors (Rakosi, Jonas and Graber, 1993).

2.2 TOOTH SIZE ANALYSIS

The natural dentition can be divided into three integral parts, two buccal segments and the anterior segment. In occlusion these parts function as units and the loss of a tooth, under or over sizing upsets the articular balance in that particular area (Neff, 1957). In Orthodontics, all teeth should be aligned so that the combined widths of the teeth will be identical with the dental arch measurement and the dental arch will be well positioned over the basal bone. Then gross differences in the dental arch, alveolar arch and basal arch perimeters will not obscure cosmetics or complicate occlusal function and stability (Moyers, 1988). The comparison of tooth size and available space determination in orthodontic treatment planning is of great clinical importance.

Table I is the summary of reported methods used to determine tooth size and arch length discrepancies.

Table I: Methods used to determine tooth size and arch length discrepancies

Author	**Year**	**Method**	**Description**	**Sample Size**	**Population Group**
Gilpatric	1923	Mathematical formula	Total mesio-distal diameter of each arch	2000	Caucasian
Wheeler	1940	Carved and articulated wax teeth in occlusion	To determine ideal occlusion based on anatomy of the tooth	-	Caucasian
Howes	1947	Mathematical ratios	Tooth size to size of supporting structure		Caucasian
Neff	1949	Mathematical formula to calculate ideal overbite	Anterior co-efficient method	200	Caucasian
Lundström	1955	Mathematical indices	To determine tooth size, arch length discrepancies	319	Caucasian
Kesling	1956	Diagnostic wax setup according to cephalometric measurements	To determine occlusion and final treatment outcome	10	Caucasian
Bolton	1958	Mathematical formula	To determine tooth size, arch length discrepancies	55	Caucasian
Howe, McNamara & O'Connor	1983	Articulation of dental casts	Arch length perimeter and area were determined by tracing buccolingual and labiolingual centres of each tooth	104	Caucasian

There is an understanding that a certain maxillary-to-mandibular tooth size relationship is important for proper occlusal relationship. In 1923, Gilpatric studied 2000 individuals and found that the total mesio-distal tooth diameters in the maxillary arch exceeded that in the mandibular arch by 8 to 12 mm (citied in Freeman, Maskeroni and Lorton, 1996).

Wheeler (1940) carved teeth in wax and articulated them. He used specific ideal dimensions which resembled natural teeth. His figures were based upon mathematically determined relationships and are therefore a good comparative guide to evaluate how closely nature approaches a mathematical formula.

Howes (1947) devised ratios for determining whether there was a need to extract premolars or whether expansion could be carried out successfully without extractions. He did this by first establishing the sum of the mesio-distal tooth material (TM) of all teeth including the first permanent molars. Thereafter he calculated the premolar diameter (PMD) by measuring the mesio-distal width of the first premolar at the coronal portion. The premolar basal arch width (PMBAW) was obtained by measuring the apical base of the first premolar on the dental cast. His first ratio was PMD ÷ TM X 100%. This ratio should equal approximately 44% of the mesio-distal widths of the twelve teeth to be sufficiently large to accommodate all the teeth. His second ratio was PMBAW ÷ TM X 100%. When the ratio between premolar basal arch width and tooth material is less than 37%, he considered this to be a basal arch deficiency necessitating extraction of premolars. If the premolar basal width was greater than the premolar coronal arch width, expansion of the premolars could be undertaken safely. Bolton's (1962) follow up study indicated the clinical application of the Bolton ratios, whereby the extraction of maxillary and mandibular first premolars during orthodontic treatment reduced the anterior and overall ratios to almost ideal. Similarly, Howes ratios indicates the necessity of premolar extractions during orthodontic treatment planning.

In 1949, Neff developed the “anterior co-efficient”, a method to compare the widths of the anterior teeth in opposing arches. The mesio-distal width of six maxillary anterior teeth were measured in millimetres using a pair of dividers. The measurements were plotted on a graph in a straight line. The same was done for the six mandibular anterior teeth. The sum of the mandibular divided by the sum of the maxillary was the anterior co-efficient. He determined that the co-efficient for an end-to-end relationship is 1.10 and for a 100 percent overlap the co-efficient is 1.52. The “ideal anterior co-efficient” for a normal, 20 percent overbite had to be 1.20 – 1.22. Neff (1949) suggested that, regardless of tooth size or shape, the maxillary anterior teeth can always be made to articulate ideally when the co-efficient is close to these figures and the mandibular incisors are in an upright relationship to the mandibular plane.

Tooth size in one jaw may not be in harmony with the tooth size in the other jaw as a result of crowding, large or small teeth and over spacing (Lundström, 1955). After measuring 319 occlusions directly in the mouth, he developed an occlusal guide called the “anterior index”. Three indices were developed to calculate the need to extract in crowded malocclusions. The relationship between the breaths of maxillary and mandibular teeth were examined. The sum of the mandibular incisors and canines divided by the sum of the maxillary incisors and canines multiplied by 100 was the first index. The sum of the maxillary bicuspids and first molars, divided by the sum of the mandibular bicuspids and first molars multiplied by 100 was the second index. The third index was the sum of all mandibular permanent teeth up to and including the first permanent molars, divided by the sum of all maxillary permanent teeth up to and including the first permanent molars multiplied by 100. The range was 73% to 85% with a mean of approximately 79%. Variations from these percentages indicated a tooth size discrepancy whereby an increased percentage indicated a need for extraction. The technique he uses to calculate his first and third indices are the same as those Bolton (1958) used to calculate his anterior and overall tooth width ratios.

Kesling (1956) rearranged plaster teeth according to Tweed's (1946) philosophy of treatment on orthodontic study models to the most desirable positions on the available apical bases, in order to assess the possibilities and limitations of the treatment. The method used was removing the teeth from the study models using a ribbon saw blade. The long axis of the mandibular incisor was set at 90° to the mandibular plane in cases where the Frankfurt-mandibular plane angle (FMPA) was 25°. As the FMPA increased by 1°, the incisor was set 1° to the lingual or 89° to the mandibular plane. This ratio was maintained until the angle reached about 33° and the mandibular incisor was placed -8° or 82° to the mandibular plane. As the teeth are positioned in their proper axial inclination, they are sealed with red setup wax. The canines are positioned in a proper relationship to the lateral incisor. If space is lacking, then other teeth such as the first or second premolars are eliminated from the setup. The maxillary teeth are then removed, articulated and positioned according to the mandibular teeth. As the plaster teeth are placed on the plaster apical base, there is evidence as to whether or not there is sufficient basal bone to accommodate all the teeth in a proper, stable position. Similarly, Bolton's (1962) study demonstrated the clinical application of his ratios by setting up maloccluded study models into ideal occlusion setups such as those of Kesling, and recalculated the ratios. Thus, he was able to determine the problematic arch and the amount of discrepancy that existed. He indicated how the extraction of certain teeth could correct the overall tooth width ratio. An existing Bolton discrepancy can be corrected by the extractions of maxillary and mandibular first premolars, or one mandibular incisor or maxillary and mandibular lateral incisors (Bolton, 1962).

Lundström (1955) developed his three indices on 319 various types of malocclusions, whereas, Bolton (1958), conducted a study to analyse a group of 55 excellent Class I occlusions. He wanted to determine whether or not mathematical ratios could be set up between total lengths of dental arches, as well as between segments of dental arches. He hoped that a method to evaluate tooth size would be found which would be an aid in diagnosis and treatment planning of orthodontic cases and also help in determining the functional and aesthetic outcome of the case. The Bolton ratios were developed by measuring the mesio-distal widths of permanent mandibular and maxillary teeth (excluding second and third molars). The sum of the widths of mandibular and maxillary teeth were recorded and expressed as a percentage. The Bolton anterior ratio (the ratio between the mesio-distal widths of the six anterior mandibular teeth and the mesio-distal widths of the six anterior maxillary teeth) and the Bolton overall ratio (the ratio between the mesio-distal widths of the twelve mandibular teeth and the mesio-distal widths of the twelve maxillary teeth, from first permanent molar to first permanent molar) were calculated as follows.

$$\text{The Bolton anterior ratio} = \frac{\text{Sum of mandibular 6 anterior teeth}}{\text{Sum of maxillary 6 anterior teeth}} \times 100$$

$$\text{The Bolton overall ratio} = \frac{\text{Sum of mandibular 12 teeth}}{\text{Sum of maxillary 12 teeth}} \times 100$$

By using the mesio-distal width of twelve teeth, Bolton (1958) obtained an overall ratio of 91.3% (SD $\pm$ 1.91%). With the six anterior teeth, he obtained an anterior ratio of 77.2% (SD $\pm$ 1.65%). The conclusion of this study was that it would be difficult for proper occlusal interdigitation or co-ordination of arches to occur in the finishing stage of orthodontic treatment, without proper mesio-distal tooth size ratio between maxillary and mandibular teeth.

The significance of the ratios, indicates a tooth size discrepancy in the mandibular and/or the maxillary arch. An overall Bolton ratio higher or lower than 91.3% indicates that the discrepancy lies in the posterior segments of either arch while an anterior Bolton ratio higher or lower than 77% indicates that the discrepancy lies in the anterior segment of either arch. The confirmation of the problematic arch is based on clinical judgment.

Bolton's ratios are preferred over other methods due to its simplicity. Anterior and overall tooth width ratios can be calculated according to Bolton's analyses, and from these norms other regression equations can be developed specific to a population group (Paredes, Gandia and Cibrian, 2006a; Othman and Harradine, 2007b; Uysal, Basciftci and Goyenc, 2009).

Kokich (2005) established that a 1% discrepancy in the Bolton anterior ratio is equivalent to 0.4mm of a linear discrepancy and a 1% discrepancy in the Bolton overall ratio is equivalent to 0.9mm of a linear discrepancy.

2.3 GENETIC INFLUENCE

Genetic influences play an important role in the determination of tooth dimensions, and the first reports were related to clinical observations within families. Garn, Lewis and Kerewsky (1965) reported that sisters are known to be more alike than brothers in developmental timing and intra-individual tooth size correlations. Their findings suggested an X-linked inheritance of tooth size. Lee *et al.,* (2007) reported on sexual dimorphism in canine size suggesting a Y-chromosome involvement, hence men have larger canines than women.

The twin-study methods by Lundström, (1949) and Horowitz, Osborne and DeGeorge, (1958) have been employed occasionally in dental and orthodontic research, in order to investigate inherited variation in tooth size and occlusion. These studies have found that there is greater variability in the size of the maxillary incisors when compared to the canines. When taking into consideration the mesio-distal tooth dimensions of anterior teeth, the incisors and canines should be considered as two separate groups. The “variable” incisors, as these teeth tend to vary in size and shape, and the relatively “stable” canines which show less variation in size and shape (Lundström, 1949; Horowitz, Osborne and DeGeorge, 1958).

Lundström (1949) reported that heredity can account for sexual dimorphism where males have larger mesio-distal tooth widths when compared with females. His twin study on siblings of different genders found that most males presented with larger mesio-distal tooth widths than their female siblings, whereas siblings of the same gender presented with fewer mesio-distal tooth width variations.

Lundström (1955) studied the variation of genetically determined tooth size of individuals and its significance in the aetiology of malocclusion. In this study he found a connection between mesio-distal tooth widths of all teeth and crowding or spacing of the arches. He reported that people with large teeth are more likely to present with crowded dentitions than people with smaller teeth. He concluded from this study that some hereditary factors affecting the dimensions of the jaw were to some extent inherited independently of other factors that determine the mesio-distal dimensions of the teeth.

Baydas, Oktay and Dağsuyu's (2005) craniometric and cephalometric study supports the hypothesis that facial form is largely a product of the person's genotype, and the size and shape of a person's teeth are also genetically determined. They conferred with Lundström (1949) that siblings of the same gender show higher heritability for anterior and overall ratios, but no statistically significant difference was observed in siblings of different genders.

Lavelle (1972) suggested that Caucasian population groups usually presented with more skeletal and dental disharmonies as a result of intermarriages and intermingling of various European communities, whereas Blacks and Asians were more homogenous skeletally and dentally. The reason for such variations and differences in tooth widths are attributed to genetic determination of tooth size and shape.

Other investigators (Uysal and Sari, 2005; Uysal, Basciftci and Goyenc, 2009) have found that a mix in the population creates a rich gene pool, such as that of the modern Turkish population who have genes from Asiatic, Turk, Balkan, Caucasian, Middle Eastern and Iranian people. Such diversity requires odontometric data established within such a genetic mix (Uysal and Sari, 2005; Uysal, Basciftci and Goyenc, 2009).

2.4 RACIAL AND ETHNIC DIFFERENCES

The method of calculating Bolton's ratios has been reported relevant when applied to an American, Caucasian sample, however, the literature suggests that this may not be applicable to all racial and ethnic groups due to a variety of racial differences (Smith, Buschang and Watanabe, 2000; Uysal and Sari, 2005). Smith, Buschang and Watanabe (2000) investigated inter-arch tooth size relationships and found that Blacks have larger maxillary canines, premolars and first molars compared to Caucasians. There were however, no differences noted for maxillary central and lateral incisors.

Lavelle (1972) conducted a comparative Bolton study on a sample of 120 study models with excellent Class I occlusion. These comprised of forty Caucasians, forty Blacks and forty Far Eastern subjects. Both the overall and anterior tooth width ratios were greater in Blacks than in Caucasians implying that Bolton's ratios over predicts the tooth size discrepancy in Black subjects. The Far Eastern subjects' ratios were intermediate. This study established that considerable tooth size differences existed among various ethnic groups, and it was reported that individuals of Black ethnic backgrounds have larger teeth than Caucasians. The population sample comprised of Caucasians from the United Kingdom, Far Eastern subjects from various parts of Asia and Black subjects who were immigrants from various parts of Africa. The sample therefore did not comprise of subjects from the same ethnic background in each of the 3 groups.

Otuyemi and Noar (1996) indicated that the mean mesio-distal tooth sizes for all teeth were significantly larger in Nigerians than in their British counterparts.

Results of studies on tooth size ratios in Hispanic populations differed significantly from Caucasians, but were similar to African-Americans. It was established that subjects of Hispanic descent presented with larger Bolton's anterior ratios than Caucasians indicating that Bolton's ratios over predicted tooth width discrepancies (Santoro *et al.*, 2000; Smith, Buschang and Watanabe, 2000). Araujo and Souki (2003) found that the great diversity and possible ethnic mix of current populations should alert the orthodontist that variations may be present when using Bolton's ratios. Their study had a stronger genetic mix of the Brazilian population and this may have been the reason for inter-arch tooth size discrepancies amongst different malocclusion groups in Brazil. A similar study was conducted on a Spanish population to determine whether Bolton's ratios are applicable. The anterior and overall tooth width ratios for the Spanish sample were found to be greater than Bolton's ratios. There was an over prediction of tooth width discrepancies when using Bolton's ratios on this sample. The differences were statistically significant and it suggested the need for specific standards to be obtained for the Spanish population (Paredes, Gandia and Cibrian, 2006a).

From these research surveys, it is evident that there are tooth size differences amongst ethnic and racial groups. As a result, race specific standards have been developed such as the studies by Bernabé, Major and Flores-Mir (2004) for their Peruvian population; Uysal and Sari (2005) for their Turkish population and Paredes, Gandia and Cibrian, (2006a) for their Spanish population. These studies have indicated that "normal" measurements for one group should not be considered "normal" for another race and ethnic group. Different racial groups must be treated according to their own characteristics (Uysal and Sari, 2005).

2.5 GENDER RELATED TOOTH SIZE DISCREPANCIES

Sexual dimorphism has been confirmed in various ethnic groups where some teeth are statistically significantly larger in male than in female subjects (Howe, McNamara and O'Connor, 1983; Uysal and Sari, 2005; Uysal, Basciftci and Goyenc, 2009).

Richardson and Malhotra (1975) measured the mesio-distal crown dimension of the permanent dentition of 162 African-Americans equally divided into males and females. The overall ratio of the mandibular dentition to the maxillary dentition was 94% for both sexes. The anterior ratio of the mandibular dentition to the maxillary dentition was 77% for both sexes. Thus, they concluded that there were no differences in maxillary and mandibular anterior tooth size proportions for both genders in their sample. Smith, Buschang and Watanabe, (2000) reported that Bolton's ratios were only applicable to White females and therefore should not be applied indiscriminately to White males, Blacks or Hispanics. They found that the overall ratio was significantly larger in males than in females. Similar odontometric studies on Black subjects show that males have larger teeth than their female counterparts (Richardson and Malhotra, 1975; Frankel and Benz, 1986; Otuyemi and Noar, 1996; Schirmer and Wiltshire, 1997; Khan, Seedat, and Hlongwa, 2007).

2.6 TOOTH SIZE DISCREPANCIES IN DIFFERENT MALOCCLUSION GROUPS

Ta, Ling and Hägg (2001) compared Bolton's ratios on a sample of a Southern Chinese sample to establish whether Bolton's ratios can be applied to an Asian sample. Their results concluded that there were significant differences in Class II and Class III malocclusions, which were more frequent in the anterior region. This was due to high variability in the size of the incisors. This study showed a tendency towards a larger Bolton anterior ratio for Class III malocclusion than any other malocclusion in the Chinese population. This was attributed to a higher variability in the size of the maxillary incisors with Southern Chinese having smaller maxillary central incisors and larger maxillary lateral incisors. Araujo and Souki (2003) reported that the mean anterior tooth size discrepancy for Angle Class III subjects was significantly greater than for Class I and Class II subjects in a Brazilian population. A similar finding where the anterior ratio of the Class III group was significantly greater than Class II Div 1 and Class II Div 2 groups, was found by Fattahi, Pakshir and Hedayati (2006) in their Iranian sample.

Some studies have found no significant differences in tooth size ratios among different Angle malocclusion groups in different populations. A study by Al-Khateeb and Alhaija (2006) on a Jordanian sample showed no significant differences between the different malocclusions. Endo *et al.,* (2008) found no significant differences in anterior or overall ratios amongst the various malocclusion groups in a Japanese population and concluded that Bolton's values can be used with confidence for this population. All subjects had normal anterior and overall ratios within $\pm$ 2 SD from Bolton's means. The millimetre measurements of these discrepancies were within

1.5mm (0.75 mm per side) which was considered too small a value to cause potential occlusal errors or to be clinically significant.

2.7 CLINICAL IMPORTANCE OF TOOTH SIZE DISCREPANCY

Bolton's (1958) initial research was carried out to determine the average ratio associated with, and permitting an excellent occlusion. In his follow up study, Bolton (1962) discussed the effect of premolar extractions on the overall ratio. He stated that premolar extractions would mathematically reduce the suggested overall mean ratio value of 91.3%. If four premolars were extracted in patients who did not present with tooth size discrepancy, then the overall mean ratio would be 88% (Othman and Harradine 2007a). Tooth thickness is an additional aspect of tooth size which affects occlusal fit, as pointed out by Bolton (1962). He stated that the ratio permitting an ideal occlusion would be influenced by the labio-lingual thickness. The Bolton ratios are a better indicator of potentially ideal occlusion if the maxillary incisors were "thinner". Proffit and Fields (2000) suggested that a quick check for anterior tooth size discrepancy can be done by comparing the size of the maxillary and mandibular lateral incisors. They proposed that unless the maxillary lateral incisors are larger, a discrepancy would exist. For posterior tooth size analysis, the size of the maxillary and mandibular second premolars, should be approximately equal in size. Othman and Harradine (2007b) reported that simple visual inspection is a poor method of detecting tooth size discrepancy. Careful and frequent measurements have to be employed in clinical practice. They suggested that tooth size discrepancies be calculated and expressed in terms of "millimetres required" for correction. By establishing norms for overall and anterior tooth width ratios, Uysal and Sari (2005) were able to develop regression equations for mixed dentition arch analyses for the Turkish population, without tooth size discrepancies (Uysal, Basciftci and Goyenc, 2009).

Arch length – tooth size discrepancies can present at the finishing stage of orthodontic treatment as generalised small spaces. A small space distal to the lateral incisor can be aesthetically and functionally restored by a composite resin build up. More generalised spacing can be masked by altering incisor position, and torquing the maxillary incisors and leaving the mandibular incisors more upright can be used to mask small maxillary incisors. It is also possible to compensate by tipping teeth or finishing with a slightly excessive overjet or overbite (Fields, 1981).

Previous studies carried out on South African Blacks, have established gender differences in mesio-distal tooth widths (Schirmer and Wiltshire, 1997; Khan, Seedat, and Hlongwa, 2007). Hence, prediction tables and equations have been formulated to determine mesio-distal tooth widths of unerupted permanent canines and premolars of South African Blacks (Schirmer and Wiltshire, 1997; Khan, Seedat, and Hlongwa, 2007). However, no studies have been done to determine tooth width discrepancies that may exist between arches on South African Blacks, hence the need for the current study.

CHAPTER 3: MATERIALS AND METHODS

3.1 MATERIALS

Study models of untreated cases with excellent occlusion were selected from the patients' records of the Department of Orthodontics archives, Medunsa Oral Health Centre, University of Limpopo. One hundred study models, as shown in Figures 1 and 2, of South African Blacks, were selected by the investigator from a sample of approximately three thousand. Selection of the study models were based on the listed selection criteria and any model that did not meet the recommended selection criteria, were not used for the study.

Figure 1. Study models (Frontal View)

Figure 2. Study models (Occlusal View)

The selection criteria for the pre-treatment orthodontic study models were as follows:

1. Study models of untreated cases with excellent occlusion, and dental records had to be of South African Blacks.
2. There had to be an equal number of male and female study models.
3. Patients had to be younger than 21 years of age. If patients are too young, some teeth that had to be measured for the purposes of this study might not have been present, and if patients were too old, inter-proximal wear and attrition may have resulted in inaccurate measurements being made.
4. Study models had to have permanent teeth fully erupted up to the first permanent molar such that the widest mesio-distal width could be seen.
5. Molars and canines had to be in Class I occlusion as described by Angle (1899) whereby the mesiobuccal cusp of the upper first molar had to occlude in the sulcus between the mesial and distal buccal cusps of the lower first molar. The mesial incline of the upper canine had to occlude with the distal incline of the lower canine (Figure 3).

Figure 3. Class I molar and canine relationship (Angle, 1899)

6. Teeth had to be well aligned with excellent occlusion.
7. There had to be a normal overjet and overbite relationship (Proffit and Fields, 2000).
8. There could not be any mesio-distal loss or an excess of tooth material as a result of caries, restorations, prosthetic replacements or gross dental abnormalities.
9. Teeth on the study models had to be free of any visible fractures, plaster voids and excess plaster.
10. Teeth could not exhibit clinically visible macrodontia or microdontia.
11. Teeth to be measured had to be free of any other pathological findings such amelogenesis imperfecta, dentinogenesis imperfecta or severe fluorosis with pitting.

One hundred (fifty males and fifty females) study models of untreated cases that met with the selection criteria were chosen. An equal number of male and female study models were used for the purpose of standardization. All study models were labelled and numbered clearly from 1 to 50 with the letter "M" before the number to signify male and the letter "F" before the number to signify female. The selected study models were then stored separately and a list of all the selected patients' details were kept for future reference (Addendum 1).

An electronic digital vernier calliper (Fowler Co. Inc., Sylvac, Switzerland) as shown in Figure 4, was used with precision to measure the mesio-distal crown widths of all permanent teeth excluding second and third permanent molars. The digital vernier calliper was used for its precise reproducibility and significant speed as compared to a manual vernier calliper (Othman and Harradine, 2007b).

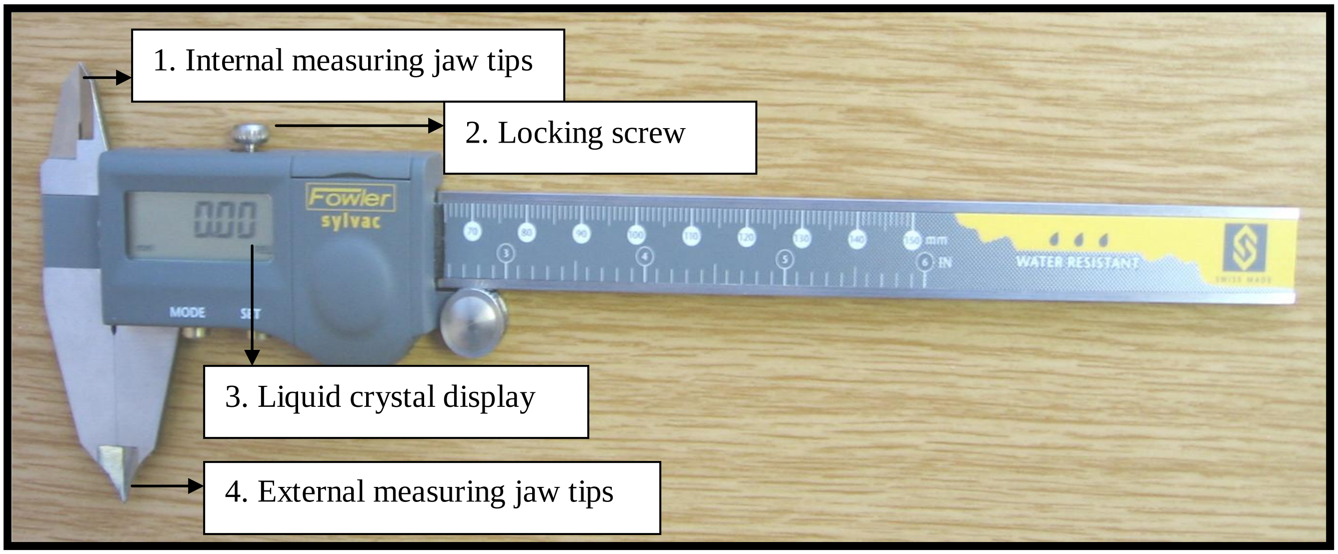

Figure 4. Digital vernier calliper

The digital vernier calliper has external and internal measuring jaw tips (Numbers 1 and 4). The external measuring jaw tips (Number 4) were used to carry out the measuring procedure. The calliper has a liquid crystal display (Number 3) where the measured values can be read. The locking screw (Number 2) once tightened after a measurement was taken, ensured that the jaw tips did not move until the measurement was recorded. The calliper was set to zero using the reset button with the jaw tips in the closed position after every reading to ensure standardization. Measurements were recorded in millimetres to two decimal places.

3.2 METHOD

The following teeth were measured from the study models:

- The permanent incisors and canines in all quadrants
- The first premolar, the second premolar and the first permanent molar in all quadrants

The study models were placed flat on a table and orientated on its posterior aspect to facilitate measuring the mesio-distal widths of the relevant teeth as shown in Figure 5. The operator was at eye level with the study model such that the contact points of the teeth that had to be measured were visible. Sharp tips of the external jaw tips facilitated accuracy of insertion and measurements. The tips of the calliper were held at 90° to the long axis of the tooth and positioned from the labial or buccal aspects of the dental cast to engage the greatest mesio-distal width of the teeth at the contact points (Hunter and Priest, 1960).

Once the tips of the digital calliper engaged the mesial and distal contact points of the tooth, the locking screw was tightened to ensure the calliper did not shift off the point where the measurement was taken. The value was read from the liquid crystal display and recorded in the appropriate data sheet especially formulated for this study as shown in Appendices A, B, C and D. Each table represented male maxillary measurements, male mandibular measurements, female maxillary measurements and female mandibular measurements.

Figure 5. Measuring of mesio-distal width of teeth is illustrated.

Readings were taken to the nearest 0.1mm for each tooth. The measurements were carried out by a single investigator who measured each tooth, from right first permanent molar to left first permanent molar for each arch three times. Ten study models were measured two hours a day, for ten days (Yeun, Tang and So, 1998). Once a tooth was measured, the correct model number and measurement from the liquid crystal display were read off and recorded by the scribe onto a data record sheet to avoid bias. Ngesa (2004) recommended that by increasing the number of times a tooth is measured reduces the chances of measurement errors. Ten pairs of pre-treatment orthodontic study models were measured per day over a period of ten days in order to reduce visual fatigue. The data was then entered into an Excel programme from the data collection sheets (Version 2002, Microsoft Corporation, Redmond, USA) to enable accuracy and efficiency of data analysis. The three measurements were then averaged using the Excel programme to maintain accuracy (Bernabé, Major and Flores-Mir, 2004).

3.3 EXAMINER RELIABILITY

Intra and inter-examiner reliabilities were tested on 20% of the sample (10 male and 10 female study models) randomly chosen. Intra-examiner reliability was tested by the main investigator, two weeks after the initial examination date. Inter-examiner reliability was tested on the same 20% of the sample measured by a second investigator (the co-supervisor) to test for reproducibility. The data collected was entered into the Excel programme (Version 2002, Microsoft Corporation, Redmond, USA) to enable accuracy and efficiency of data analysis. The inter and intra examiner reliability was tested using the paired *t* test.

3.4 STATISTICAL ANALYSIS

Demographic data of the patients represented by the study models were summarized by descriptive statistics. Tooth width comparisons were done using the 2-Sample *t* test to establish gender differences. For each group the mean, standard deviation and coefficient of variation were calculated. Tooth width ratios were thereafter calculated for each gender. Gender differences for the mean anterior as well as the overall tooth width ratios between males and females were tested by comparing 95% confidence intervals, and by hypothesis testing (2-Sample *t* tests).

The anterior and overall tooth width ratios (%) were calculated for each study model using an Excel programme. For analytical purposes the following four groups were identified:

- Group 1: Males' anterior tooth width ratio (n=50)
- Group 2: Females' anterior tooth width ratio (n=50)
- Group 3: Males' overall tooth width ratio (n=50)
- Group 4: Females' overall tooth width ratio (n=50)

The tooth width ratios for the select sample of South African Blacks were then compared to Bolton's original sample using the 2-Sample *t* test. The null hypotheses Ho: $\mu=77.2$ and Ho:$\mu=91.3$ were tested for the combined datasets for the anterior and overall tooth width ratios respectively (1-Sample *t* test). All statistical procedures were performed on SAS®, Release 9.1.3, run under Microsoft® Windows® XP for a personal computer. All statistical tests were two-sided and p values ≤ 0.05 were considered significant.

CHAPTER 4: RESULTS

4.1 AGE DISTRIBUTIONS

The sample consisted of 100 study models of a select group of South African Blacks (50 males and 50 females). Table II shows a breakdown of the descriptive statistics with regard to the age of the sample. The mean age for the male sample was 15.5 years $\pm$ 3 years (range = 11 to 21 years). The mean age for the female sample was 16.26 years $\pm$ 2.54 years (range = 10 to 21 years).The mean age for the female sample was higher than that of the male sample. However, the mean ages of males and females did not differ significantly (2-Sample *t* test, $p = 0.76$).

Table II: Age distribution of the select sample of South African Blacks

Sample	**Number**	**Mean age**	**SD**	**Minimum**	**Maximum**	***p* Value**
Females	50	16.26	2.54	10.00	21.00	0.76
Males	50	15.50	3.05	11.00	21.00	
p Value significant at $p \leq 0.05$						

The sample was further divided into four groups according to age range for both males and females. Figures 6 and 7 show graphically the age range distribution according to gender. The highest number for both male and female subjects were in the age range of 13 to 15 years respectively.

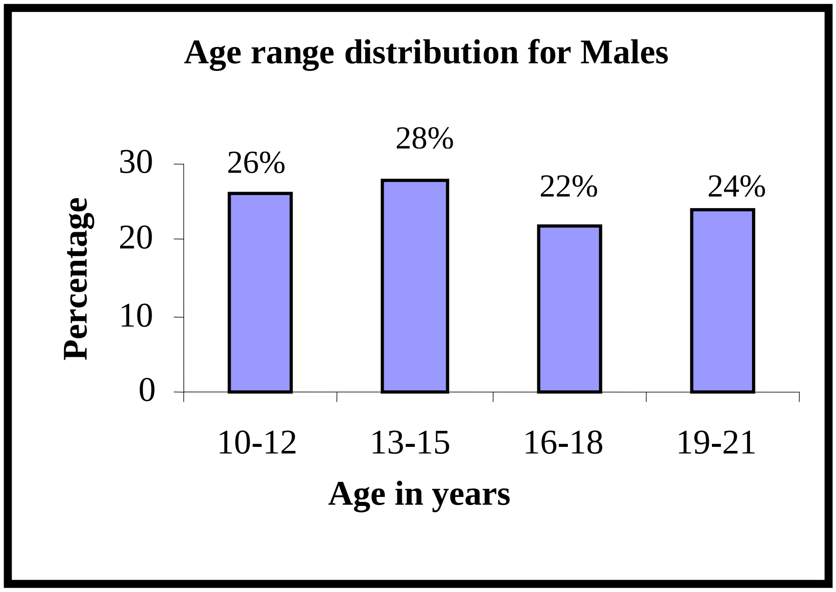

Figure 6. Age range distribution for the male sample

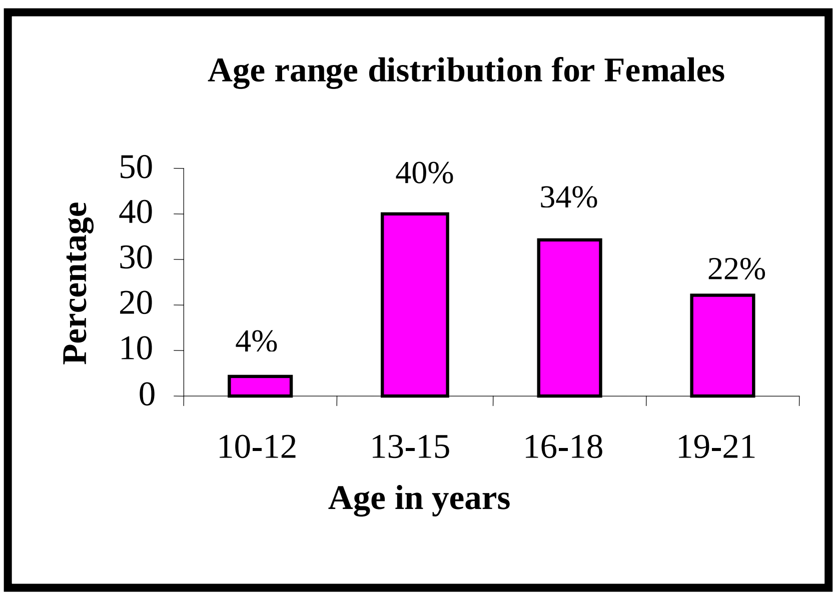

Figure 7. Age range distribution for the female sample

4.2 EXAMINER RELIABILITY TESTS

Intra-examiner reliability was assessed on 20 randomly selected study models re-measured by the main investigator. Inter-examiner reliability was assessed by comparing mean anterior and overall tooth width ratios measured by a second investigator (the co-supervisor) on the same randomly selected sample. Intra-examiner and inter-examiner reliability showed no statistical significant differences between original and repeated measurements. This indicated that the method of measurement was reliable and reproducible.

Means and standard deviations of the calculations are reflected in Table III

Table III: Examiner reliability on 20% of the select sample of South African Blacks

Examiner	**N**	**Mean**	**SD**	**Min**	**Max**	**Paired *t* test *p* Value**
Intra examiner reliability for anterior tooth width ratio	20 20	76.86 77.08	3.08 2.90	70.40 70.59	83.34 83.55	0.206
Intra examiner reliability for overall tooth width ratio	20 20	92.08 92.33	2.28 2.11	87.75 87.85	96.10 96.36	0.130
Inter examiner reliability for anterior tooth width ratio	20 20	76.86 77.71	3.08 3.23	70.40 71.82	83.34 85.32	0.153
Inter examiner reliability for overall tooth width ratio	20 20	92.08 92.86	2.28 3.10	87.75 88.77	96.10 103.41	0.224
p Values are not significant						

4.3 GENDER COMPARISON OF TOOTH WIDTHS IN THE SAMPLE

Tables IV and V compare the mesio-distal tooth widths between males and females in the maxillary and mandibular arches respectively, using the 2-Sample *t* test.

Table IV: Maxillary Tooth Width Comparison between Males and Females

Tooth	Gender	N	Mean (mm)	SD	Minimum	Maximum	*p* Value
T11	M	50	9.43	0.73	7.56	11.17	<0.001*
	F	50	8.95	0.51	7.99	10.18	
T12	M	50	7.79	0.80	5.69	9.89	<0.001*
	F	50	7.31	0.57	6.05	8.59	
T13	M	50	8.26	0.53	7.40	9.47	<0.001*
	F	50	7.73	0.36	7.15	8.57	
T21	M	50	9.45	0.71	8.08	11.17	<0.001*
	F	50	8.92	0.50	8.04	9.98	
T22	M	50	7.68	0.75	5.78	9.21	<0.001*
	F	50	7.17	0.64	5.47	8.31	
T23	M	50	8.17	0.57	6.76	9.49	<0.001*
	F	50	7.63	0.36	7.00	8.50	
T14	M	50	7.69	0.51	6.80	9.13	0.007*
	F	50	7.42	0.46	6.23	8.35	
T15	M	50	7.10	0.54	6.09	8.32	0.035*
	F	50	6.87	0.50	5.52	7.92	
T16	M	50	10.87	0.68	9.18	12.59	<0.001*
	F	50	10.41	0.51	9.46	11.66	
T24	M	50	7.70	0.52	6.49	9.36	0.011*
	F	50	7.43	0.51	6.09	8.28	
T25	M	50	7.10	0.58	5.94	8.42	0.020*
	F	50	6.85	0.47	5.69	7.67	
T26	M	50	10.80	0.64	8.92	12..23	0.003*
	F	50	10.45	0.51	9.25	11.72	
*p Value significant at $p \leq 0.05$							

Table V: Mandibular Tooth Width Comparison between Males and Females

Tooth	Gender	N	Mean (mm)	SD	Minimum	Maximum	*p* Value
T31	M	50	5.79	0.42	5.11	7.06	<0.001*
	F	50	5.47	0.31	4.94	6.24	
T32	M	50	6.38	0.49	5.37	7.65	<0.001*
	F	50	6.09	0.35	5.26	7.19	
T33	M	50	7.55	0.56	6.48	9.10	<0.001*
	F	50	6.90	0.37	5.93	8.00	
T41	M	50	5.76	0.47	4.78	6.77	0.005*
	F	50	5.52	0.34	4.84	6.41	
T42	M	50	6.31	0.52	5.30	7.57	<0.001*
	F	50	6.02	0.31	5.35	6.98	
T43	M	50	7.44	0.55	6.41	9.01	<0.001*
	F	50	6.85	0.42	5.82	7.87	
T34	M	50	7.89	0.50	6.82	9.41	<0.001*
	F	50	7.56	0.40	6.70	8.45	
T35	M	50	7.71	0.59	6.47	9.56	<0.001*
	F	50	7.37	0.43	6.37	8.63	
T36	M	50	11.99	0.99	8.04	14.05	0.003*
	F	50	11.50	0.49	10.22	12.45	
T44	M	50	7.85	0.55	6.65	9.38	<0.001*
	F	50	7.49	0.43	6.64	8.33	
T45	M	50	7.67	0.58	6.57	9.01	0.004*
	F	50	7.36	0.46	6.39	8.60	
T46	M	50	11.97	0.77	9.97	13.62	<0.001*
	F	50	11.46	0.48	10.42	12.36	
*p Value significant at $p \leq 0.05$							

There was a statistical significant difference in the sizes of individual teeth between males and females. All p values ≤ 0.05 are statistically significant which implies that for all teeth the mean values of males and females differ significantly. The mean value for males were found to be larger than the mean value for females.

4.4 GENDER COMPARISON OF ANTERIOR TOOTH WIDTH RATIO

$$\text{The anterior tooth width ratio} = \frac{\text{Sum of mandibular 6 anterior teeth}}{\text{Sum of maxillary 6 anterior teeth}} \times 100$$

The anterior tooth width ratio was calculated for each individual of the male and female sample, and the mean, range and standard deviation are summarised in Table VI.

Table VI: Gender comparison of the anterior tooth width ratios calculated in the sample

Sample	**N**	**Mean %**	**SD**	**Minimum**	**Maximum**	***p* Value**
Females	50	77.29	2.28	70.40	82.13	0.90
Males	50	77.23	2.99	71.11	83.46	
p Value significant at $p \leq 0.05$						

The mean values for males and females anterior tooth width ratio were compared by the 2-Sample *t* test (H_0: $\mu_M = \mu_F$ against H_1: $\mu_M \neq \mu_F$). There was no statistical significant difference found in the anterior tooth width ratio. The *p* value of 0.90 was not significant, which implied that the means of the two genders do not differ significantly.

4.5 GENDER COMPARISON OF OVERALL TOOTH WIDTH RATIO

$$\text{The overall tooth width ratio} = \frac{\text{Sum of mandibular 12 teeth}}{\text{Sum of maxillary 12 teeth}} \times 100$$

Similarly the overall tooth width ratio was calculated for each individual of the male and female sample, and the mean, range and standard deviation are summarised in Table VIII.

Table VII: Gender comparison of the overall tooth width ratio calculated in the sample

Sample	**N**	**Mean %**	**SD**	**Minimum**	**Maximum**	***p* Value**
Females	50	92.25	1.62	87.75	95.45	0.76
Males	50	92.38	2.33	86.99	97.50	
p Value significant at $p \leq 0.05$						

The mean values for males and females overall tooth width ratios were compared by the 2-Sample *t* test (H_0: $\mu_M = \mu_F$ against H_1: $\mu_M \neq \mu_F$). The *p* value of 0.76 was not statistically significant which implied that the means of the two genders did not differ significantly.

Since the mean tooth width ratios of the two genders did not differ significantly in anterior and overall tooth width ratios they were combined into one group for anterior tooth width ratio and another group for overall tooth width ratio.

4.6 COMBINED SAMPLE OF MALES AND FEMALES COMPARED TO BOLTON'S RATIOS

It was found that for all teeth, the mean width for males was always greater than the mean width for females. However, when expressed as mathematical ratios (anterior as well as overall tooth width ratios) no significant differences were found between the mean indices for males and females. Therefore, the male and female groups were combined into one group. The anterior and overall tooth width ratios of the current sample were compared to Bolton's (1958) original ratios derived from a Caucasian sample. The null hypotheses Ho: $\mu=77.2$ and Ho: $\mu=91.3$ were tested for the combined dataset for the anterior and overall tooth width ratios respectively (Student's *t* test) and the *p* values are reflected in Table VIII.

Table VIII: Combined anterior and overall tooth width ratios compared to Bolton's original ratios

Sample	**N**	**Mean**	**SD**	***p* Value**
Study sample anterior ratio	100	77.26	2.65	0.82
Bolton's anterior ratio	55	77.20	1.65	
Study sample overall ratio	100	92.31	2.00	<0.0001*
Bolton's overall ratio	55	91.30	1.91	

**p* Value significant at $p \leq 0.05$

The mean value of the study sample anterior tooth width ratio was 77.26%. The mean value of the study sample overall tooth width ratio was 92.31%.

The *p* value for the study sample anterior tooth width ratio compared to Bolton's original ratio was not statistically significant. The sample mean ratio of 77.26% was similar to that of Bolton's anterior ratio (Ho: μ=77.2). The *p* value for the overall ratio was statistically significant ($p < 0.0001$). The sample mean ratio of 92.31% differed significantly from Bolton's original overall ratio (Ho: μ=91.3).

A ninety five percent confidence interval implies that with 95% confidence, the true mean value falls within two limits (a range). The 95% confidence interval for the mean of Bolton's anterior tooth width ratio was 77.20% ± 0.44 = (76.77% ; 77.64%). The 95% confidence interval for the mean of Bolton's overall tooth width ratio was 91.30% ± 0.51 = (90.79% ; 91.81%).

Thus 95% confidence intervals were calculated for the study sample anterior and overall tooth width ratios respectively with the following results. The 95% confidence interval for the mean of the study sample anterior tooth width ratio was 77.26% ± 0.52 = (76.74% ; 77.78%). The 95% confidence interval for the mean of the study sample overall tooth width ratio was 92.31% ± 0.39 = (91.92% ; 92.70%). The confidence intervals are graphically displayed in Figure 8 as an error bar graph.

The range for the study sample's anterior tooth width ratio falls within the range for Bolton's anterior tooth width ratio. However, the range for the study sample's overall ratio falls outside the range for Bolton's overall tooth width ratio indicating statistically significant difference.

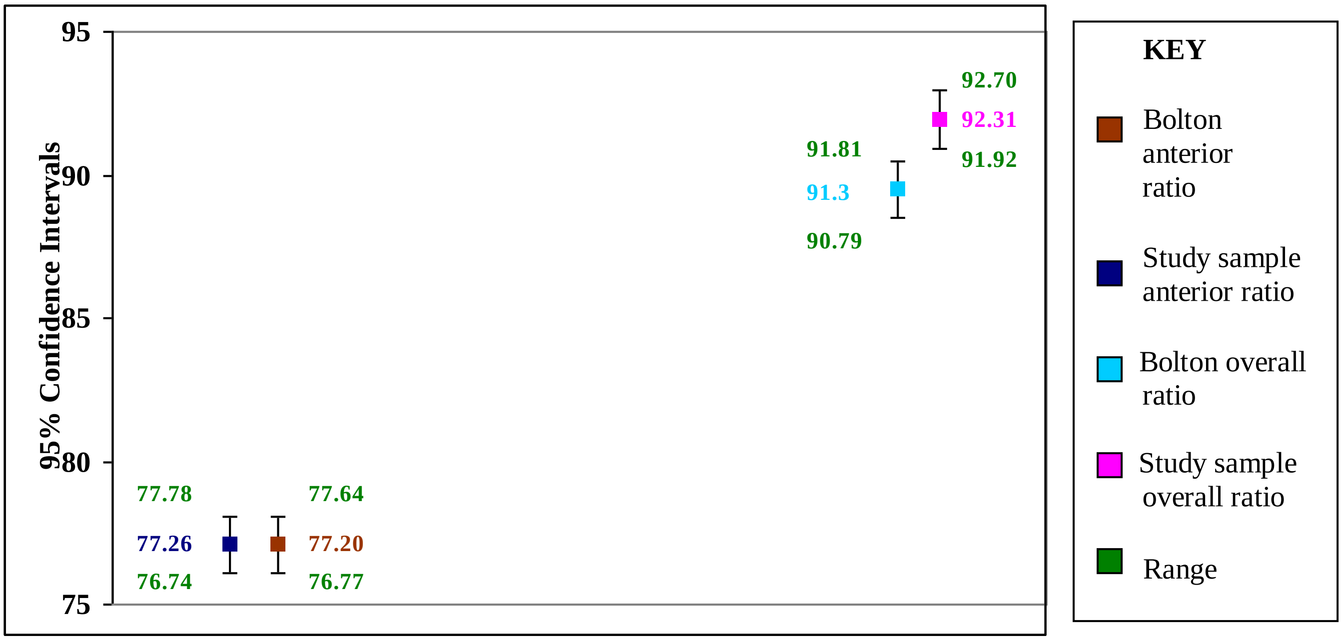

Figure 8. Ninety five percent confidence intervals of anterior and overall tooth width ratios illustrated as an error bar graph

CHAPTER 5: DISCUSSION

5.1 AGE DISTRIBUTION

The mean age for the male and female samples were 15.5 years $\pm$ 3 years and 16.26 years $\pm$ 2.54 years respectively. The mean age of this study was in keeping with that of Santoro *et al.,* (2000) whose sample age range was 12 to 22 years, and Al-Khateeb and Alhaija (2006) whose sample age range was 13 to 15 years.

In this study, the highest number of boys (n=14) and girls (n=20), were in the age range of 13 to 15 years (Figures 6 and 7). The teeth that were required to perform this study are usually present at this age range, hence most of the sample falls within this age group. This age group of the sample also represents the age range of most young patients who seek orthodontic treatment. Al-Khateeb and Alhaija (2006) selected a group of teenagers from this age range to minimize the alteration of the mesio-distal tooth dimensions because of factors such as attrition, restorations and caries. If patients were too young, some teeth that had to be measured might not have been present such as the premolars, and if patients were too old, inter-proximal wear and attrition would have resulted in inaccurate measurements being made. There was one 10 year old female patient in our sample who was in complete permanent dentition, indicating early dental maturation.

Contrary to the current study, Uysal and Sari's (2005) sample had an older age range with the males in their sample having a mean age of 22 years while the females had a mean age of 21 years. Uysal and Sari (2005) selected a sample of 150 patients in the age range of 20 to 35 years, with more mature and balanced facial features to minimise skeletal and dental variability that occurs with growth. This is also an indication of the increasingly large number of adult patients seeking orthodontic treatment. In our current study, 23% of the sample were in the adult age range of 19 to 21 years.

5.2 EXAMINER RELIABILTY

The intra-examiner and inter-examiner reliability was tested using the paired *t*-test (Table III). Results showed no significant differences between the repeated and the original measurements for anterior and overall tooth width ratios ($p>0.05$). Due to the relatively small sample size, 20% of the sample was re-measured to ensure that the methodology was accurately followed. The difference in the inter-examiner and intra-examiner reliability for anterior and overall tooth width ratios were 0.63% and 0.53% respectively. This was within 1 SD of the anterior and overall tooth width ratios. Hunter and Priest (1960) reported that if the mean difference between investigators were less than 1 SD, then this magnitude of difference may be of no practical significance. These findings corroborate favourably with other studies whereby the method of measurement of the mesio-distal widths of teeth employed in this study was reliable and reproducible (Hunter and Priest, 1960; Yeun, Tang and So, 1998; Paredes, Gandia and Cibrian, 2006a; Khan, Seedat, and Hlongwa, 2007).

5.3 GENDER COMPARISON OF TOOTH WIDTHS

The mesio-distal dimensions of all individual teeth were measured and compared between genders. The female group presented with smaller teeth than the males. Other studies have reported similar findings where boys were reported to have generally larger teeth than girls in all the segments (Paredes, Gandia and Cibrian, 2006a; Othman and Harradine, 2007b; Uysal, Basciftci and Goyenc, 2009).

Bilateral symmetry of mesio-distal tooth widths of contra-lateral teeth in each arch for both genders was found. Although slight variability differences were found in the range of 0 - 0.14 mm in the maxillary lateral incisors of females, this was not statically significant. Therefore the right and the left quadrants were combined to obtain one value. Bilateral symmetry of mesio-distal tooth widths has been found in other odontometric studies (Moorrees and Reed, 1964; Richardson and Malhotra, 1975; Otuyemi and Noar, 1996; Khan, Seedat, and Hlongwa, 2007).

The maxillary anterior teeth of the males in the current sample were on average 3.07 mm larger than that of their female counterparts. The difference in the maxillary posterior segment was on average 1.83 mm larger in the males than the females. Similarly the difference in the size of the mandibular anterior teeth was on average 2.38 mm whilst the difference in the mandibular posterior segment was on average 2.34 mm. Statistically significant differences were also found for all teeth when the mean mesio-distal tooth widths of males were compared with those of the females (Tables IV and V).

The significant difference in tooth widths between males and females in this current study confirms previous results published on a Jordanian population by Hattab, Al-Khateeb and Sultan (1996) and Al-Khateeb and Alhaija (2006) and the South African study on a Black sample by Khan, Seedat, and Hlongwa (2007) whereby males presented with larger mesio-distal tooth widths of maxillary and mandibular canines and premolars than the females. The similarity of our study with these previous studies is that the main tooth size difference between the two genders was demonstrated in the canines, molars, and the sum of the tooth widths in both arches. The maxillary teeth of the females showed greater variability than the mandibular teeth compared to those of males. This could be as a result of the maxillary first molar and the maxillary lateral incisor being highly variable teeth (Santoro *et al.,* 2000).

Differences also exist between genders of various races where it has been reported that Black males have larger teeth than Caucasian males. Smith, Buschang and Watanabe (2000) reported that Black males had larger maxillary canines, premolars and first molars compared to Caucasian males, whilst Black females have generally larger teeth than Caucasian females. Sexual dimorphism in tooth dimensions can be attributed to genetic and environmental factors. In a cluster analysis of tooth size between genders, Lee *et al.,* (2007) found that canine size had a Y-chromosome involvement. They also suggested that in males, developmental timing is more extended than in females, thus increasing the opportunity to be influenced by environmental factors.

5.4 GENDER COMPARISON OF TOOTH WIDTH RATIOS

A total maxillary tooth width dimension of 102.04 mm and 97.14 mm for males and females respectively was found. The mandibular tooth width dimension was 94.31 mm and 89.59 mm for males and females respectively. There were no differences in tooth width ratios when expressed as percentages between the two genders of this select sample of South African Blacks. The anterior tooth width ratio of 77.2% and the overall tooth width ratio of 92.3% were found for both genders. Similarly, Richardson and Malhotra (1975) found that the tooth widths of Black North American males were larger than those of their female counterparts for all teeth in both arches. The total maxillary tooth width dimension of their sample was 122.52 mm and 117.54 mm for males and females respectively, whilst the total mandibular tooth width dimension was 115.26 mm and 110.94 mm for males and females respectively. Similarly to the current study, they did not find differences in anterior and posterior inter-arch tooth width ratios, even though their anterior tooth width ratio was 77% and the overall tooth width ratio was 94% in both genders.

Smith, Buschang and Watanabe (2000) reported that males had slightly larger tooth width ratios than females in a Hispanic sample. These differences were reported to be very small at 0.7% on the overall ratio and 0.6% on the anterior ratio (less than 1 SD) and therefore they used the same tooth width ratios for both genders. The results of the current study could be compared to these, even though the male mesio-distal tooth width dimensions were larger than the females for all teeth, when expressed as anterior and overall tooth width ratios there were minimal differences between the genders. The differences in the anterior and overall tooth width ratios for this select sample of South African Blacks were 0.06% and 0.13% respectively. Since these values were also less than 1 SD they were not considered significant and the same ratios were therefore used for both genders. It is for this reason that the two genders were combined into one group in this study.

5.5 APPLICABILITY OF BOLTON'S RATIOS

Table IX: Anterior and Overall tooth width ratios for various population groups

Study	**Sample**	**Anterior Tooth Width Ratio**	**Overall Tooth Width Ratio**
Bolton (1958)	Caucasian (American)	77.2%	91.3%
Crosby and Alexander (1989)	Caucasian (American)	77.5%	91.4%
Smith, Buschang and Watanabe (2000)	Caucasian (American)	79.6%*	92.3%*
Fernandez-Riveiro, Suárez-Quintanilla and Otero-Cepeda (1995)	Spanish (Spain)	80.6%*	93.4%*
Paredes, Gandia and Cibrian (2006a)	Spanish (Spain)	78.3%*	91.9%
Smith, Buschang and Watanabe (2000)	Spanish (South American)	80.5%*	93.1%*
Santoro *et al.*, (2000)	Dominican Americans	78.1%*	91.3%
Richardson and Malhotra (1975)	Blacks (American)	77%	94%*
Smith, Buschang and Watanabe (2000)	Blacks (American)	79.3%*	93.4%*
Bernabé, Major and Flores-Mir (2004)	Peruvian	78%*	90.8%*
Current Study	Blacks (South African)	77.2%	92.3%*
* Significantly different from Bolton's ratios			

The 95% confidence intervals for this study were higher than that in Bolton's (1962) study for the anterior and overall tooth width ratios. Paredes, Gandia and Cibrian (2006a) who also had higher means, SD and 95% confidence intervals compared to Bolton's (1958) study, suggested that larger sample size (N = 100) and different ethnic group (Spanish) to be the reasons for their higher values.

The overall tooth width ratio reported for the select sample of South African Blacks were similar for overall ratio reported by Smith, Buschang and Watanabe, (2000). However, unlike the current study Smith, Buschang and Watanabe, (2000) found the anterior tooth width ratios significantly larger than 2 SD of Bolton's anterior ratio. Studies that did concur with Bolton's overall ratios were those by Crosby and Alexander (1989) and Santoro *et al.* (2000). A similarity among these studies is that, no gender differences in anterior and overall tooth width ratios were reported (Table IX).

Smith, Buschang and Watanabe (2000) reported that Blacks have larger maxillary canines, premolars and first molars than Caucasians, even though there are no differences for maxillary central or lateral incisors. They found that the overall tooth width ratio for Caucasians in their sample was 92.3% whereas the overall tooth width ratio for Blacks was 93.4%. The difference in the overall ratios was due to the larger mesio-distal tooth widths of the posterior segments. There was no significant difference in the anterior tooth width ratios between Blacks and Caucasians reported. The larger overall tooth width ratio obtained in the select sample of South African Blacks can be attributed to the larger mesio-distal tooth widths of canines and premolars reported in South African Blacks compared to Caucasians (Schirmer and Wiltshire, 1997; Khan, Seedat, and Hlongwa, 2007).

The current study evaluated 100 of study models of untreated cases with excellent occlusion. No interproximal stripping or reduction in mesio-distal tooth widths were done in order to achieve ideal occlusion. However unlike Bolton's (1958) study which comprised of a sample of 55 patients with excellent occlusion of which 80% of this sample consisted of post-treatment study models of non extraction cases. Bolton's ratios were formulated from this sample even though no treatment mechanics were described on how ideal occlusion were achieved.

In clinical orthodontics, more often than not, interproximal stripping is instituted in non-extraction cases to achieve space for final alignment. The clinical application of Bolton's ratios were described by Bolton (1962) indicating that extraction of certain teeth or interproximal stripping should be employed if a discrepancy in the ratios occurs. Therefore interproximal stripping in a non-extraction case will change the Bolton ratio.

Bolton (1962) suggested that a SD greater than 2 indicates a tooth size discrepancy and only then should it be considered clinically significant. In order to establish the upper and lower limits (range) for a mean, the SD is not merely added and subtracted to the mean, but a statistical equation is used (Dawson-Saunders and Trapp, 1994).

$$\text{Confidence interval} = X \pm t \times SD \div \sqrt{N}$$

Where X is the mean of the study sample, t is the critical value or constant, SD is the standard deviation and N is the sample size (Dawson-Saunder and Trapp, 1994).

Therefore when taking into consideration the SD of Bolton's overall ratio (SD 1.91) and anterior ratio (SD 1.65), the ranges are calculated as follows:

$$91.3 \pm 1.96 \; (1.91 / \sqrt{55}) = 91.3 \pm 0.506$$
$$= (90.79 \; ; \; 91.81)$$

$$77.20 \pm 1.96 \; (1.65 / \sqrt{55}) = 77.20 \pm 0.435$$
$$= (76.77 \; ; \; 77.64)$$

When considering the SD of the study sample's overall ratio (SD 2) and anterior ratio (SD 2.65), the ranges are calculated as follows:

$$92.3 \pm 1.96 \; (2 / \sqrt{100}) = 92.31 \pm 0.392$$
$$= (91.92 \; ; \; 92.70)$$

$$77.26 \pm 1.96 \; (2.65 / \sqrt{100}) = 77.26 \pm 0.519$$
$$= (76.74 \; ; \; 77.78)$$

Therefore the SD of Bolton's ratios cannot be considered without the SD of the study sample. The range for the anterior ratio of the study sample falls within the range for Bolton's anterior ratio. The p value is 0.82 which indicates no statistical significance (Table VIII). However the range for the study sample's overall ratio does not fall within the range of Bolton's overall ratio. The p value of $p < 0.0001$ is highly significant (Table VIII).

The studies by Richardson and Malhotra, (1975); Smith, Buschang and Watanabe, (2000); Santoro *et al.,* (2000); Fernandez-Riveiro, Suárez-Quintanilla and Otero-Cepeda, (1995); Bernabé, Major and Flores-Mir (2004); and Paredes, Gandia and Cibrian, (2006a) all reported overall tooth width ratios within 2 SD of Bolton's overall ratio, however these differences were reported to be highly statistically significant. It is for this reason that Fernandez-Riveiro, Suárez-Quintanilla and Otero-Cepeda, (1995) suggested values outside 1 SD and not 2 SD to be statistically significant (Paredes, Gandia and Cibrian, 2006a). The anterior and overall tooth width ratios developed from these studies are the recommended norms for their respective population groups.

Bernabé, Major and Flores-Mir (2004) found that the lower range of 2 SD for the anterior ratio was clinically significant, whereas just 1 SD for the overall ratio was clinically significant. They concluded that 2 SD for the overall ratio would be a gross tooth-width ratio discrepancy. They were able to conclude the amount of linear discrepancy that was present because their sample comprised of different malocclusions. The current study could not establish clinical discrepancies as the sample consisted of untreated cases with excellent Class I occlusion and therefore the results are based on statistical significance only.

It is therefore recommended that the newly proposed overall ratio of 92.3% be used for this sample as Bolton's overall ratio under calculates the amount of linear space by 0.9 mm for every 1% increase or decrease in the overall tooth width ratio, indicating mild crowding in one arch or spacing in the other arch (Kokich, 2005). The anterior ratio that is recommended for the select sample of South African Blacks does not differ from Bolton's anterior ratio.

5.6 CONCLUSION

The null hypothesis was accepted for the anterior tooth width ratio for the study sample as the Bolton anterior ratio was applicable to this sample and there were no gender differences. However, it was rejected for the overall tooth width ratio as the range for the current study fell outside the range of Bolton's overall ratio, as depicted by an error bar graph in Figure 8. The study sample's anterior ratio of 77.2% is within the same range as Bolton's anterior ratio of 77.26% which can be used when determining the tooth size, arch length discrepancy in the anterior segment. The Bolton overall ratio of 91.3% under calculates the amount of tooth material in the mandibular arch implying there is a discrepancy when the teeth are occluding in a harmonious relationship.

The newly proposed ratios for this sample are as follows:

$$\text{Anterior ratio} = \frac{\text{Sum of mandibular 6 anterior teeth}}{\text{Sum of maxillary 6 anterior teeth}} \times 100 = 77.2\%$$

$$\text{Overall ratio} = \frac{\text{Sum of mandibular 12 teeth}}{\text{Sum of maxillary 12 teeth}} \times 100 = 92.3\%$$

5.7 RECOMMENDATIONS

Genetics, hereditary and environmental factors play a role in the aetiology of malocclusion (Lundström, 1949; Horowitz, Osborne and DeGeorge, 1958; Uysal, Basciftci and Goyenc, 2009). It is almost impossible to carry out this study on a true ethnic Black sample because South Africa is a multiracial, multi-cultural society with inter-marriages and a diverse mix of ethnicity. South African Caucasians are also a large ethnic mix of German, Dutch and Portuguese descent (Ramerini, 2009). According to the mid-year population estimates released by Statistics South Africa in 2009, South Africa is still broadly classified into four population race groups. 79.3% of the population are categorised as African, 9% Coloured, 2.6% Indian and 9.1% White (Lehohla, 2009). It is recommended that research be undertaken to assess whether Bolton's ratios which were derived from a North American Caucasian sample would be applicable to a sample of South African Caucasians.

Bolton's (1958) study, as well as the current study were carried out on subjects with Class I normal occlusion (Angle, 1899). It is recommended that a study be done on a sample with Class I, Class II and Class III malocclusions. Nie and Lin (1999) conducted a study on 360 cases divided equally into Class II and Class III malocclusions. They found larger values in anterior and overall ratios in Class III malocclusions whilst smaller values were found in Class II malocclusions. Class II malocclusions are commonly seen in Caucasians (El-Mangoury and Mostafa, 1990) while Class III malocclusions are common amongst Blacks (Proffit, Fields and Moray, 1998). Ta, Ling and Hägg (2001) found larger anterior tooth width ratios for their Southern Chinese sample with Class III malocclusions. If a Bolton discrepancy is the contributing factor to a Class II or Class III malocclusion, it will be interesting to establish the extraction pattern of upper and/or lower premolars during camouflage orthodontic treatment of Class II and Class III malocclusions. Bolton (1962) stated that, after 4 premolar extractions, subjects without a tooth size discrepancy would have overall ratios of 87% to 89%. On this basis, orthodontists must take into consideration the decrease in overall ratios and formulate treatment plans accordingly.

The method of measuring the mesio-distal tooth widths of individual teeth manually is a laborious task and a digital method of doing so is an attractive alternative. Technological advancements in orthodontics have now made it possible to digitise the images of dental arches with the aid of a computer programme, whereby the tooth width ratios are simply and automatically calculated without the use of a vernier calliper (Paredes, Gandia and Cibrian, 2006b). A comparative study can be done in the near future to validate results obtained in the current study.

REFERENCES

Al-Khateeb, S.N. & Alhaija, E.S.J.A. (2006). Tooth size discrepancies and arch parameters among different malocclusions in a Jordanian sample. *Angle Orthodontist,* **76**: 459-465.

Andrews, L. F. (1972). The six keys to normal occlusion. *American Journal of Orthodontics and Dentofacial Orthopedics,* **62**:296.

Angle, E.H. (1899). Classification of malocclusion. *Dental Cosmos,* **41**: 248-264; 370-371.

Araujo, E. & Souki, M. (2003). Bolton anterior tooth size discrepancies among different malocclusion groups. *Angle Orthodontist,* **73**: 307-313.

Basaran, G., Selek, M., Hamamci, O. & Akkus, Z. (2006). Intermaxillary Bolton tooth size discrepancies among different malocclusion groups. *Angle Orthodontist,* **76**: 26-30.

Baydas, B., Oktay, H. & Dağsuyu, I.M. (2005). The effect of heritability on Bolton tooth-size discrepancy. *European Journal of Orthodontics,* **27**: 98-102.

Bernabé, E., Major P.W. & Flores-Mir, C. (2004). Tooth-width ratio discrepancies in a sample of Peruvian adolescents. *American Journal of Orthodontics and Dentofacial Orthopedics,* **125**: 361-365.

Bolton, W.A. (1958). Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. *Angle Orthodontist,* **28**: 113-130.

Bolton, W.A. (1962). The clinical application of a tooth size analysis. *American Journal of Orthodontics*, **48:** 504-529.

Crosby, D.R. & Alexander, C.G. (1989). The occurrence of tooth size discrepancies among different malocclusion groups. *American Journal of Orthodontics and Dentofacial Orthopedics*, **95**: 457-461.

Dawson-Saunders, B. & Trapp, R.G. (1994). *Basic and Clinical Biostatistics*. 2nd Ed. Appleton and Lange, Connecticut, USA, pp 103.

El-Mangoury, N.H. & Mostafa, Y.A. (1990). Epidemiologic panorama of dental occlusion. *Angle Orthodontist*, **60**: 207-214.

Endo, T., Abe, R., Kuroki, H., Oka, K. & Shimooka, S. (2008). Tooth size discrepancies among different malocclusions in a Japanese orthodontic population. *Angle Orthodontist*, **78:** 994-999.

Fattahi, H.R., Pakshir, H.R. & Hedayati, Z. (2006). Comparison of tooth size discrepancies among different malocclusion groups. *European Journal of Orthodontics*, **28:** 491-495.

Fernandez-Riveiro, P., Suárez-Quintanilla, D., & Otero-Cepeda, J.L (1995). Análisis odontométrico de una población maloclusiva: Indice de Bolton. *Revista Española de Ortodoncia*, **25**: 119-126. In Paredes, V., Gandia, J.L. & Cibrian, R. (2006a). Do Bolton's ratios apply to a Spanish population? *American Journal of Orthodontics and Dentofacial Orthopedics*, **129**: 428-430.

Fields, H.W. (1981). Orthodontic-restorative treatment for relative mandibular anterior excess tooth size problems. *American Journal of Orthodontics and Dentofacial Orthopedics,* **79:** 176-183.

Frankel, H.H. & Benz, E.M. (1986). Mixed dentition analysis for Black American. *Pediatric Dentistry,* **8:** 226-230.

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.

Garn, S.M., Lewis, A.B. & Kerewsky, R.S. (1965). X-linked inheritance of tooth size. *Journal of Restorative Dentistry,* **44:** 476-479.

Gilpatric, W.H. (1923). Arch predetermination – is it practical? *Journal of the American Dental Association,* 553-557.

Hattab, F.N., Al-Khateeb, S. & Sultan, I. (1996). Mesiodistal crown diameters of permanent teeth in Jordanians. *Archives of Oral Biology,* **41:** 641-645.

Horowitz, S.L., Osborne, R.H. & DeGeorge, F.V. (1958). Hereditary factors in tooth dimensions: a study of anterior teeth of twins. *Angle Orthodontist,* **28**: 87-93.

Howes, A.E. (1947). Case analysis and treatment planning based upon the relationship of the tooth material to its supporting bone. *American Journal of Orthodontics and Dentofacial Orthopedics,* **33:** 499-533.

Howe, R.P., McNamara, J.A. & O’Connor, K.A. (1983). An examination of dental crowding and its relationship to tooth size and arch dimension. *American Journal of Orthodontics and Dentofacial Orthopedics,* **83:** 363-373.

Hunter, W.S. & Priest, W.R. (1960). Errors and discrepancies in measurement of tooth size. *Journal of Dental Research,* **39:** 740-748.

Kesling, H.D. (1956). The diagnostic setup with consideration of the third dimension. *American Journal of Orthodontics,* **42**: 29-37.

Khan, M.I., Seedat, A.K., & Hlongwa, P. (2007). Tooth width predictions in a sample of Black South Africans. *South African Dental Journal,* **62:** 224-249.

Kokich, V.G. (2005). Early management of congenitally missing teeth. *Seminars in Orthodontics.* **11**: 146-151.

Lavelle, C.L. (1972). Maxillary and mandibular tooth size in different racial groups and in different occlusal categories. *American Journal of Orthodontics,* **61**: 29-37.

Lee, S.J., Lee, S., Lim, J., Ahn, S.J. & Kim, T.W. (2007). Cluster analysis of tooth size in subjects with normal occlusion. *American Journal of Orthodontics and Dentofacial Orthopedics,* **132:** 796-800.

Lehohla, P.J. (2009). Statistics South Africa, mid-year population estimates. Statistical Release P0302. http://www.statssa.gov.za, pp. 4.

Lundström, A. (1949). Size of the teeth and jaws in twins. *British Dental Journal,* **87:**297.

Lundström, A. (1955). Variation of tooth size in the aetiology of malocclusion. *American Journal of Orthodontics,* **41:** 872-876.

Moorrees, C.F.A. & Reed, R.B. (1964). Correlations among crown diameters of human teeth. *Archives of Oral Biology,* **9:** 685-697.

Moyers, R.E. (1988). *Handbook of Orthodontics.* 4th ed. Chicago: Yearbook, pp. 363.

Neff, C.W. (1949). Tailored occlusion with the anterior co-efficient. *American Journal of Orthodontics,* **35**: 309-313.

Neff, C.W. (1957). The size relationship between the maxillary and mandibular anterior segments on the dental arch. *Angle Orthodontist,* **27**: 138-147.

Ngesa, J.L. (2004). Applicability of tooth size predictions in the mixed dentition analysis in a Kenyan sample. [Dissertation]. University of Western Cape.

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.

Othman, S.A. & Harradine, N.W. (2007a). Tooth-size discrepancy and Bolton's ratios: the reproducibility and speed of two methods of measurement. *Journal of Orthodontics,* **34**: 234-242.

Othman, S.A. & Harradine, N.W. (2007b). Tooth size discrepancies in an orthodontic population. *Angle Orthodontist,* **77**: 668-674.

Otuyemi, O.D. & Noar, J.H. (1996). A comparison of crown size dimensions of permanent teeth in a Nigerian and a British population. *European Journal of Orthodontics,* **18:** 623-628.

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

Paredes, V., Gandia, J.L. & Cibrian, R. (2006b). Determination of Bolton tooth-size ratios by digitization, and comparison with the traditional method. *European Journal of Orthodontics,* **28**: 120-125.

Proffit, W.R., Fields, H.W. & Moray, L.J. (1998). Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES-III survey. *International Journal of Adult Orthodontics and Orthognathic Surgery*. **13**: 97-106.

Proffit, W.R. & Fields, H.W.Jnr. (2000). *Contemporary Orthodontics*, 3rd ed. St Louis:Mosby, pp. 10, 13, 170-171.

Rakosi, T., Jonas, I. & Graber, T.M. (1993). *Color atlas of dental medicine (orthodontic diagnosis)*. Thieme Medical Publishers, New York, pp. 228-230.

Ramerini, M. (2009). The Dutch heritage in South Africa. http://www.colonialvoyage.com/afrikaans.html

Richardson, E.R. & Malhotra, S.K. (1975). Mesiodistal crown dimension of the permanent dentition of American Negroes. *American Journal of Orthodontics*, **68**: 157-164.

Santoro, M., Ayoub, M.E., Pardi, V.A. & Cangialosi, T.J. (2000). Mesiodistal crown dimensions and tooth size discrepancy of permanent dentition of Dominican Americans. *Angle Orthodontist*, **70**: 303-307.

Schirmer, U.R., & Wiltshire, W.A. (1997). Orthodontic probability tables for Black patients of African descent: Mixed dentition analysis. *American Journal of Orthodontics and Dentofacial Orthopedics*, **112**: 545-551.

Smith, S.S., Buschang, P.H. & Watanabe, E. (2000). Interarch size relationships of 3 populations: does Bolton's analysis apply? *American Journal of Orthodontics and Dentofacial Orthopedics,* **117**: 169-174.

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.

Tweed, C.H. (1946). Frankfurt-mandibular plane angle in orthodontic diagnosis, classification, treatment planning and prognosis. *American Journal of Orthodontics,* **32:**175-230.

Uysal, T. & Sari, Z. (2005). Intermaxillary tooth size discrepancy and mesiodistal crown dimensions for a Turkish population. *American Journal of Orthodontics and Dentofacial Orthopedics,***128:** 226-230.

Uysal, T., Sari, Z., Basciftci, F.A. & Memili, B. (2005). Intermaxillary tooth size discrepancy and malocclusion: Is there a relation? *Angle Orthodontist,* **75**: 204-209.

Uysal, T., Basciftci, F.A. & Goyenc, Y. (2009). New regression equations for mixed dentition arch analysis in a Turkish sample with no Bolton tooth size discrepancy. *American Journal of Orthodontics and Dentofacial Orthopedics,* **135:** 343-347.

Wheeler, R.C. (1940). *Textbook of Dental Anatomy and Physiology*. 4th Ed. W.B. Saunders, Philadelphia, pp. 14-16.

Yuen, K.K., Tang, E.L. & So, L.L. (1998). Mixed dentition analysis for Hong Kong Chinese. *Angle Orthodontist*, **68**: 21-28.

APPENDICES

APPENDIX A : MALE MAXILLARY MEASUREMENTS

MODEL NO MAXILLA (MALE)	11	12	13	21	22	23	TOTAL ANTERIOR	BOLTON ANTERIOR	14	15	16	24	25	26	TOTAL OVERALL	BOLTON OVERALL
M1																
AVG																
M2																
AVG																
M3																
AVG																
M4																
AVG																
M5																
AVG																
M6																
AVG																
M7																
AVG																
M8																
AVG																
M9																
AVG																
M10																
AVG																

APPENDIX B : MALE MANDIBULAR MEASUREMENTS

MODEL NO MANDIBULAR (MALE)	31	32	33	41	42	43	TOTAL ANTERIOR	BOLTON ANTERIOR	34	35	36	44	45	46	TOTAL OVERALL	BOLTON OVERALL
M1																
AVG																
M2																
AVG																
M3																
AVG																
M4																
AVG																
M5																
AVG																
M6																
AVG																
M7																
AVG																
M8																
AVG																
M9																
AVG																
M10																
AVG																

APPENDIX C : FEMALE MAXILLARY MEASUREMENTS

MODEL NO MAXILLA (FEMALE)	11	12	13	21	22	23	TOTAL ANTERIOR	BOLTON ANTERIOR	14	15	16	24	25	26	TOTAL OVERALL	BOLTON OVERALL
F1																
AVG																
F2																
AVG																
F3																
AVG																
F4																
AVG																
F5																
AVG																
F6																
AVG																
F7																
AVG																
F8																
AVG																
F9																
AVG																
F10																
AVG																

APPENDIX D : FEMALE MANDIBULAR MEASUREMENTS

MODEL NO MANDIBULAR (FEMALE)	31	32	33	41	42	43	TOTAL ANTERIOR	BOLTON ANTERIOR	34	35	36	44	45	46	TOTAL OVERALL	BOLTON OVERALL
F1																
AVG																
F2																
AVG																
F3																
AVG																
F4																
AVG																
F5																
AVG																
F6																
AVG																
F7																
AVG																
F8																
AVG																
F9																
AVG																
F10																
AVG																

ADDENDA

1. PRE-TREATMENT STUDY CASTS NUMBERS AND PATIENT INFORMATION

Male Sample			
Model No	**File No**	**Ortho No**	**Age in yrs**
M1	0206598	0393	13
M2	0403868	04262	14
M3	0407432	04436	12
M4	0111478	01333	14
M5	0404145	04264	12
M6	0406058	04542	19
M7	0402248	04069	12
M8	2004178	00283	19
M9	0407205	04437	15
M10	9806566	98124	12
M11	0409858	04538	14
M12	9603112	96040	21
M13	0203066	01334	17
M14	0202295	0255	15
M15	0403869	04223	15
M16	0402380	04286	21
M17	0212196	03226	14
M18	9902187	99046	20
M19	2004178	00283	19
M20	0209119	3061	18
M21	0208777	0480	12
M22	0201259	0381	12
M23	0303068	03167	19
M24	0404775	04539	11
M25	0306058	03401	14
M26	0201141	0436	12
M27	0308832	03304	19
M28	0210711	03228	18
M29	0208747	0484	11
M30	0208777	0480	12
M31	0306536	03338	18
M32	0403892	04210	15
M33	2000525	00167	20
M34	0312307	04029	12
M35	0303811	03199	16
M36	9804154	98131	14
M37	0208741	0465	15
M38	0406003	04367	14
M39	0408055	04414	16
M40	0409272	04509	20
M41	0210059	0551	20
M42	9804510	98189	19

M43	0406789	04404	16
M44	01025404	0148	19
M45	20090101	00277	11
M46	9610654	0425	17
M47	0407658	04471	14
M48	0407010	04381	16
M49	0202321	0428	18
M50	0205405	0454	12

Female Sample			
Model No	**File No**	**Ortho No**	**Age in yrs**
F1	0404104	04230	16
F2	0403827	04217	14
F3	0304226	04562	13
F4	2003642	03292	13
F5	0409681	04540	21
F6	0307875	04213	19
F7	0203203	0562	18
F8	2012081	04563	13
F9	9712413	98025	14
F10	0302750	3114	16
F11	0209182	0502	15
F12	0303653	03198	12
F13	0207327	0371	15
F14	0304015	03183	16
F15	0212321	3056	17
F16	0112030	03200	18
F17	9907154	0343	16
F18	2011433	0199	13
F19	0309654	03390	19
F20	0407597	04518	15
F21	9707215	98011	17
F22	0404122	04248	15
F23	0203632	04303	10
F24	0300442	03293	20
F25	0103329	01169	14
F26	0108432	01189	15
F27	0107660	01212	19
F28	0308760	03402	18
F29	0406169	040362	14
F30	0409599	04475	15
F31	0407027	04401	16
F32	0404039	04479	15
F33	0501372	0576	17
F34	0204148	3008	14
F35	9206443	0118	14
F36	0404813	04271	21
F37	9804325	98181	15

F38	9802620	98104	19
F39	9910374	01215	19
F40	2005279	00163	15
F41	0202538	0205	16
F42	0405198	04285	18
F43	9804371	98130	17
F44	9209488	99094	18
F45	0112188	0445	18
F46	0203568	0239	17
F47	0408790	04478	19
F48	9604123	01335	14
F49	2008811	3079	13
F50	02098548	0552	20

2. BASIC STATISTICS OF AGE DISTRIBUTION

--- GENDER=F --------------------------------

The FREQ Procedure

nage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
10-12	2	4.00	2	4.00
13-15	20	40.00	22	44.00
16-18	17	34.00	39	78.00
19-21	11	22.00	50	100.00

--- GENDER=M --------------------------------

The FREQ Procedure

nage	Frequency	Percent	Cumulative Frequency	Cumulative Percent
10-12	13	26.00	13	26.00
13-15	14	28.00	27	54.00
16-18	11	22.00	38	76.00
19-21	12	24.00	50	100.00

3 BASIC STATISTICS OF INDIVIDUAL TEETH

----------------------------------- GENDER=F -----------------------------------

The MEANS Procedure

Variable	Label	N	Mean	Std Dev	Minimum	Maximum
T11	T11	50	8.95	0.51	7.99	10.18
T12	T12	50	7.31	0.57	6.05	8.59
T13	T13	50	7.73	0.36	7.15	8.57
T21	T21	50	8.92	0.50	8.04	9.98
T22	T22	50	7.17	0.64	5.47	8.31
T23	T23	50	7.63	0.36	7.00	8.50
T14	T14	50	7.42	0.46	6.23	8.35
T15	T15	50	6.87	0.50	5.52	7.92
T16	T16	50	10.41	0.51	9.46	11.66
T24	T24	50	7.43	0.51	6.09	8.28
T25	T25	50	6.85	0.47	5.69	7.67
T26	T26	50	10.45	0.51	9.25	11.72
T31	T31	50	5.47	0.31	4.94	6.24
T32	T32	50	6.09	0.35	5.26	7.19
T33	T33	50	6.90	0.37	5.93	8.00
T41	T41	50	5.52	0.34	4.84	6.41
T42	T42	50	6.02	0.31	5.35	6.98
T43	T43	50	6.85	0.42	5.82	7.87
T34	T34	50	7.56	0.40	6.70	8.45
T35	T35	50	7.37	0.43	6.37	8.63
T36	T36	50	11.50	0.49	10.22	12.45
T44	T44	50	7.49	0.43	6.64	8.33
T45	T45	50	7.36	0.46	6.39	8.60
T46	T46	50	11.46	0.48	10.42	12.36

---------------------------------- GENDER=M ----------------------------------

Variable	Label	N	Mean	Std Dev	Minimum	Maximum
T11	T11	50	9.43	0.73	7.56	11.17
T12	T12	50	7.79	0.80	5.69	9.89
T13	T13	50	8.26	0.53	7.40	9.47
T21	T21	50	9.45	0.71	8.08	11.17
T22	T22	50	7.68	0.75	5.78	9.21
T23	T23	50	8.17	0.57	6.76	9.49
T14	T14	50	7.69	0.51	6.80	9.13
T15	T15	50	7.10	0.54	6.09	8.32
T16	T16	50	10.87	0.68	9.18	12.59
T24	T24	50	7.70	0.52	6.49	9.36
T25	T25	50	7.10	0.58	5.94	8.42
T26	T26	50	10.80	0.64	8.92	12.23
T31	T31	50	5.79	0.42	5.11	7.06
T32	T32	50	6.38	0.49	5.37	7.65
T33	T33	50	7.55	0.56	6.48	9.10
T41	T41	50	5.76	0.47	4.78	6.77
T42	T42	50	6.31	0.52	5.30	7.57
T43	T43	50	7.44	0.55	6.41	9.01
T34	T34	50	7.89	0.50	6.82	9.41
T35	T35	50	7.71	0.59	6.47	9.56
T36	T36	50	11.99	0.99	8.04	14.05
T44	T44	50	7.85	0.55	6.65	9.38
T45	T45	50	7.67	0.58	6.57	9.01
T46	T46	50	11.97	0.77	9.97	13.62

4. HYPOTHESIS TESTING

The UNIVARIATE Procedure
Variable: nant_ratio

Moments

N	100	Sum Weights	100
Mean	0.0595	Sum Observations	5.95
Std Deviation	2.6463504	Variance	7.00317045
Skewness	0.18128417	Kurtosis	-0.0472571
Uncorrected SS	693.6679	Corrected SS	693.313875
Coeff Variation	4447.64774	Std Error Mean	0.26463504

Basic Statistical Measures

Location		Variability	
Mean	0.05950	Std Deviation	2.64635
Median	-0.38500	Variance	7.00317
Mode	-0.39000	Range	13.06000
		Interquartile Range	3.61000

Test	-Statistic-		-----p Value------	
Student's t	t	0.224838	Pr > |t|	0.8226
Sign	M	-5	Pr >= |M|	0.3682
Signed Rank	S	-16.5	Pr >= |S|	0.9551

Quantiles (Definition 5)

Quantile	Estimate
100% Max	6.260
99%	6.255
95%	4.615
90%	3.730
75% Q3	2.020
50% Median	-0.385
25% Q1	-1.590
10%	-3.350
5%	-3.925

The UNIVARIATE Procedure
Variable: nant_ratio

Quantiles (Definition 5)

Quantile	Estimate
1%	-6.445
0% Min	-6.800

Extreme Observations

----Lowest----		----Highest---	
Value	Obs	Value	Obs
-6.80	40	4.74	74
-6.09	60	4.93	8
-4.58	39	6.14	94
-4.15	70	6.25	68
-4.05	51	6.26	98

Variable: nOverall_ratio

Moments

N	100	Sum Weights	100
Mean	1.0128	Sum Observations	101.28
Std Deviation	2.00042979	Variance	4.00171935
Skewness	-0.0867942	Kurtosis	-0.106458
Uncorrected SS	498.7466	Corrected SS	396.170216
Coeff Variation	197.51479	Std Error Mean	0.20004298

Basic Statistical Measures

Location		Variability	
Mean	1.01280	Std Deviation	2.00043
Median	1.10000	Variance	4.00172
Mode	-2.28000	Range	10.51000
		Interquartile Range	2.77500

5. INTER AND INTRA EXAMINER RELIABILITY

The MEANS Procedure

Analysis Variable : ant13

N	Mean	Std Dev	Pr > |t|
20	0.23	0.77	0.2025

Variable	N	Mean	Std Dev	Pr > |t|
ant12	20	-0.63	2.45	0.2650
ant23	20	0.86	2.58	0.1534

The MEANS Procedure

Analysis Variable : overall_13

N	Mean	Std Dev	Pr > |t|
20	0.24	0.69	0.1298

Variable	N	Mean	Std Dev	Pr > |t|
overall_12	20	-0.54	2.62	0.3720
overall_23	20	0.78	2.77	0.2241

6. COMPARISON OF TOOTH WIDTH RATIOS OF STUDY SAMPLE TO BOLTON'S RATIOS

-- Gender=F --

The CORR Procedure

3 Variables: Overall_01 Overall_02 Overall_03

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Overall_01	10	91.85900	2.32951	918.59000	87.85000	94.88000	Overall_01
Overall_02	10	93.10800	4.19673	931.08000	88.77000	103.41000	Overall_02
Overall_03	10	91.64900	2.37840	916.49000	87.75000	94.80000	Overall_03

Pearson Correlation Coefficients, N = 10
Prob > |r| under H0: Rho=0

	Overall_ 01	Overall_ 02	Overall_ 03
Overall_01	1.00000	0.53718	0.99765
Overall_01		0.1093	<.0001
Overall_02	0.53718	1.00000	0.53707
Overall_02	0.1093		0.1094
Overall_03	0.99765	0.53707	1.00000
Overall_03	<.0001	0.1094	

-- Gender=M --

The CORR Procedure

3 Variables: Overall_01 Overall_02 Overall_03

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Overall_01	10	92.79400	1.85666	927.94000	90.45000	96.36000	Overall_01
Overall_02	10	92.61600	1.58589	926.16000	90.20000	96.03000	Overall_02
Overall_03	10	92.51700	2.20959	925.17000	88.81000	96.10000	Overall_03

Pearson Correlation Coefficients, N = 10
Prob > |r| under H0: Rho=0

	Overall_ 01	Overall_ 02	Overall_ 03
Overall_01	1.00000	0.87395	0.89731
Overall_01		0.0009	0.0004
Overall_02	0.87395	1.00000	0.67798
Overall_02	0.0009		0.0312
Overall_03	0.89731	0.67798	1.00000
Overall_03	0.0004	0.0312	

CORRELATIONS FOR OVERALL MEASUREMENTS
PRINTOUT NUMBER 4

The CORR Procedure

3 Variables: Overall_01 Overall_02 Overall_03

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Overall_01	20	92.32650	2.10558	1847	87.85000	96.36000	Overall_01
Overall_02	20	92.86200	3.09803	1857	88.77000	103.41000	Overall_02
Overall_03	20	92.08300	2.27826	1842	87.75000	96.10000	Overall_03

Pearson Correlation Coefficients, N = 20
Prob > |r| under H0: Rho=0

	Overall_01	Overall_02	Overall_03
Overall_01	1.00000	0.54966	0.95383
Overall_01		0.0121	<.0001
Overall_02	0.54966	1.00000	0.50329
Overall_02	0.0121		0.0237
Overall_03	0.95383	0.50329	1.00000
Overall_03	<.0001	0.0237	

7. ORAL AND POSTER PRESENTATION FOR THE HATTON POSTGRADUATE COMPETITION, IADR, 2009

IADR, AFRICA AND MIDDLE EAST REGION/
KDA JOINT CONFERENCE 2009

KENYA DENTAL ASSOCIATION

Certificate of Participation

This is to Certify that

Shivani Singh

Attended the 2nd Africa and Middle East Region (AMER) Conference held

on

23rd - 25th September 2009

in

Mombasa, Kenya

Convenor *Conference Secretary* *National Chair, KDA*