APPLICABILITY OF TOOTH SIZE PREDICTIONS IN THE MIXED DENTITION ANALYSIS IN A KENYAN SAMPLE

by

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KEY WORDS

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ABSTRACT

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Mixed dentition space analysis forms a critical aspect of early orthodontic treatment. The two most widely used non-radiographic tooth size prediction methods were derived from populations of Northern European ancestry. However, the applicability of these methods in other ethnic groups has been varied and questionable. The aim of this study is to evaluate the accuracy of the Tanaka and Johnston (1974) and the Moyers (1988) methods in a Kenyan sample. Mesio-distal tooth widths of 131 sets of dental casts obtained from randomly selected patients (50 males; 81 females) attending Kenyatta National Hospital were measured. The mean sum of the four mandibular incisors was used to determine the sum of canine and the two premolars in one quadrant. The predicted values of the mesio-distal widths were statistically compared with their respective actual sum of the canine and premolars of the same quadrants. The results of paired t tests and scatterplots indicated that there were highly significant differences ($p<0.003$) between actual measurements (∑ 3, 4 & 5) and their predicted values from Moyers (1988) prediction method except at 85% and/or 95% confidence levels. However, Tanaka and Johnston (1974) failed to show any statistically significant differences for either sex and combined sexes at $p<0.05$. The Tanaka and Johnston (1974) method was the most accurate among the non-radiographic prediction methods in the mixed dentition analysis in the Kenyan sample.

DECLARATION

I, JAMES LWANGA NGESA, declare that APPLICABILITY OF TOOTH SIZE PREDICTIONS IN THE MIXED DENTITION ANALYSIS IN A KENYAN SAMPLE is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

DR JAMES LWANGA NGESA, BDS (NBI)

Signed Date

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DEDICATION

This thesis is dedicated to my wife, Anne A. Ngesa; my family; friends; and colleagues whose patience, support and guidance have made my study of Orthodontics possible.

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ABBREVIATIONS

The following abbreviations are used in this thesis:

∑ 3, 4 & 5:	Combined sum of permanent canine, first and second premolars in one quadrant
C:	Canines
Ci:	Central incisors
Diff.:	Differences
LC:	Left canine
LCi:	Left central incisor
Li:	Lateral incisors
LLi:	Left lateral incisor
LPm1:	Left first premolar
LPm2:	Left second premolar
mm:	Millimetres
Mn:	Mandible
Mx:	Maxilla
Pm1:	First premolars
Pm2:	Second premolars
r:	Coefficient of correlation

r^2:	Coefficient of determination
RC:	Right canine
RCi:	Right central incisor
RLi:	Right lateral incisor
RPm1:	Right first premolar
RPm2:	Right second premolar
SD:	Standard deviation
SEE:	Standard error of estimate

CHAPTER I

INTRODUCTION

1 INTRODUCTION

Early treatment is becoming increasingly popular in the orthodontic circles and it is imperative that the mixed dentition space analysis is accurately done before such orthodontic treatment is offered (Cunat, 1982; Proffit and Fields, 2000). Prominent among the conditions requiring early attention are those in which there is disparity between the amount of the dental arch space and the amount of tooth material, which should be accommodated (Huckaba, 1964). In planning the most expeditious management of such cases it is imperative that any deficit of arch space be predicted in advance and the indicated procedures instituted early (Huckaba, 1964, Proffit and Fields, 2000).

An accurate mixed dentition space analysis is one of the important criteria in determining whether the treatment plan may involve serial extraction, guidance of eruption, space maintenance, space regaining or just periodic observation of the patients (Smith et al., 1979; Cunat, 1982; Lee-Chan et al., 1998, Bishara and Jakobsen, 1998). There have been instances in which space maintaining appliances were placed in areas where space was already grossly inadequate, with the result that tooth extraction was necessary along with orthodontic space closure of the very space which was held open. The consequence, of course, was a needless appliance, an unnecessary expense, and a protraction of orthodontic treatment (Huckaba, 1964).

Tooth size prediction of the unerupted permanent canines, first and second premolars forms part of the critical aspects of the mixed dentition space analysis. Three main approaches have been used to estimate the mesio-distal crown widths of the permanent canines and premolars in the mixed dentition patients:

i) Measurement of the unerupted teeth on the radiographs (Nance, 1947; Bull, 1959; Huckaba, 1964).

ii) Use of the regression equations that relate the mesio-distal widths of erupted teeth to the mesio-distal widths of unerupted teeth (Moyers, 1958, 1973,1988; Tanaka and Johnson, 1974).

iii) A combination of measurements from erupted teeth and radiographs of unerupted teeth (Hixon and Oldfather, 1958; Staley and Hoag, 1978; Staley and Kerber, 1980; Staley et al., 1979, 1983, 1984).

The most accurate predictions of the mesio-distal widths of unerupted canines and premolars can be obtained by measurements of mesio-distal widths of these teeth on radiographs combined with measurement of mesio-distal widths of the erupted mandibular permanent teeth (Irwin et al., 1995; Proffit and Fields, 2000). However, it requires the use of dental casts and radiographs to complete the analysis (Wangpichit et al., 2001).

In many clinical situations in the developing countries the availability of the dental x-ray machines is inadequate and quality of the available radiographic films is questionable. Kenya, being one of the developing countries, has scarce resources that are being directed mainly to combating more life threatening health conditions. Therefore, the availability of the dental x-ray machines is still too inadequate to be employed in the general management of patients in most of its oral health delivery centres. Due to these economic limitations the radiographic based prediction methods would not offer enough solutions to the general management of these patients. Therefore, the non-radiographic approaches (use of dental casts alone) would be the best in the Kenyan situation. Additionally, it has been reported that the most commonly used non-radiographic approaches are not as accurate in other ethnic groups as they are in Caucasian populations (Frankel and Benz, 1986; Schirmer and Wiltshire, 1997). This is because these non-radiographic methods (Moyers, 1973, 1988; Tanaka and Johnston, 1974) were derived from patients of Northern European descent (Proffit and Fields, 2000).

1.1 Rationale of this study

Orthodontists rarely see early mixed dentition patients first in Kenya but the dentists have the first opportunity of examining these cases and thus can predict the course of development in order that proper assessment can be made. If this prediction is accurately made, and if those patients who are faced with developing malocclusions are properly referred, the incidence of dental irregularities in adult dentitions would probably be reduced. On the other hand, it is fruitless to refer patients who are only suspected of having such orthodontic problems when in reality, no problem exists (Huckaba, 1964). Furthermore, it has been reported in some developed countries that intraoral radiographs presented for consultations by dentists in public dental service (Collett, 1980; Svenson et al., 1995) have been of questionable quality. The quality of dental films is probably poorer in developing countries, and thus use of radiographic prediction techniques may not provide an accurate estimation of tooth size in their populations.

There are probably large differences in tooth size among subgroups of blacks and using one set of standards for all populations with same racial classification could lead to serious errors clinically (Bailit, 1975). There have been several studies of two non-radiographic methods (Moyers, 1973; 1988; Tanaka and Johnston, 1974) in other population groups, which concluded that both methods underestimated the tooth dimensions in the non-Caucasian samples (Schirmer and Wiltshire, 1997; Jaroontham and Godfrey, 2000; Diagne et al., 2003). Both Tanaka and Johnston (1974) and Moyers (1988) at 75% have been found to overestimate the tooth size in Caucasian samples (Bishara and Jakobsen, 1998; Wangpichit et al., 2001; Legovic et al., 2003). Clinically, direct measurement from the radiographs would be the best approach of determining the size of unerupted teeth on children whose genetic background is not European, such as Blacks and Orientals (White, 1978; Proffit and Fields, 2000). However, in occasions where the parent/patient are unwilling to allow for the needed radiographs, the clinicians may have to use nonradiographic methods for predicting the unerupted permanent canines and premolars (Bishara and Jakobsen, 1998).

In view of the related problems as discussed above and since no similar studies of these non-radiographic methods have been reported in any Kenyan sample, this study was designed to evaluate the applicability of Tanaka and Johnston (1974) and Moyers (1988) methods in predicting the size of permanent canines and premolars in a Kenyan Sample.

CHAPTER II

LITERATURE REVIEW

2 LITERATURE REVIEW

Orthodontic treatment in the mixed dentition is largely dependent upon an accurate space analysis. It is well documented in the orthodontic literature that space analysis involves the comparison between the amount of space available for the alignment of teeth and the amount of space required to place them in the correct position (Sim, 1972; Moyers, 1973, 1988; Cunat, 1982; Proffit and Fields, 2000).

Several approaches have been devised either to estimate the space available (Huckaba, 1964) or space required (Nance, 1947; Hixon and Oldfather, 1958; Staley and Kerber, 1980; Moyers, 1973, 1988; Tanaka and Johnston, 1974) for mixed dentition space analysis.

2.1 Determination of Dental Arch Perimeter

This is basically accomplished:

i) Either by dividing the dental arch into segments which are approximately straight lines (Huckaba, 1964),

ii) By contouring a piece of brass wire to the line of occlusion and then straightening out for measurement. However, the definition of the line of occlusion is quite varied in the literature (Proffit and Fields, 2000), or

iii) Computerized approaches based on the above principles (Proffit and Fields, 2000).

Determining of the space available in the mixed dentition analysis has three assumptions:

i) It assumes that the incisors are neither protrusive nor retrusive (Proffit and Fields, 2000).

ii) It does not predict the amount of natural decrease in perimeter, which may occur during the transitional period without the loss of teeth (Moyers, 1988).

iii) It assumes that growth changes will not significantly affect the treatment in the mixed dentition (Moyers, 1988; Proffit and Fields, 2000).

2.2 Determination of Unerupted tooth size

Human tooth size is largely determined genetically with limited influence from extremes of environmental factors such as malnutrition (Horowitz et al., 1958; Lundstrom, 1964; Bailit, 1975; Garn, 1977; Doris et al., 1981). However, accumulated evidence indicates that tooth size reflects a complex interaction between a variety of genetic and environmental factors (Bailit, 1975; Townsend and Brown, 1978; Garn et al., 1979; Harzer, 1987) and thus exhibits a continuous range of variations among individuals and between population groups (Hattab et al., 1996). Marked racial differences in tooth size have been reported in the literature (Richardson and Malhotra, 1975; Lysell and Myrberg, 1982; Bishara et al., 1989; Al-Khadra, 1993; Hattab et al., 1996; Yuen et al., 1998). Differences in tooth sizes between the different sexes averages four per cent of the combined size, and is greatest in the maxillary canine and least for incisors (Garn et al., 1964; Moyers, 1988). X-chromosome mediated inheritance has also been reported (Garn et al., 1965; 1967). A few investigators have noted a secular trend towards an increase in tooth size with succeeding generations (Garn et al., 1968; Lavelle, 1972). Furthermore, tooth size and jawbone sizes seem to be under separate control mechanisms (Garn, 1977; Harzer, 1987). Crown morphogenesis is believed to be determined by interaction of polygenic and environmental factors (Garn, 1977).

Prediction of the size of unerupted teeth presents a great challenge to both dentists and orthodontists. Prediction methods are based on the fact that once crown morphogenesis is complete; the teeth are less susceptible to postnatal modifying factors (Bishara et al., 1986; Moyers, 1988). Although, several methods for the tooth size prediction of unerupted teeth have been suggested in the literature, their applicability and accuracy is varied and still questionable in different ethnic groups (Schirmer and Wiltshire, 1997; Lee-Chan et al., 1998). Since space evaluation is so important in many areas of mixed dentition treatment and major treatment decisions are based on differences involving a very few millimetres, it would be of great advantage to both the dentist and orthodontist to use as accurate a method of tooth size prediction as possible in a specific population group (Wangpichit et al., 2001).

Prediction methods based on mesio-distal widths of erupted permanent teeth and/or dimensions of radiographic images of unerupted teeth usually employ simple or multiple linear regressions. The use of several predictors in multiple linear regressions may improve the prediction, though they may be very complicated for clinical use. However, if an appropriate predictor is chosen for simple linear regression analysis, accuracy can still be acceptable (Staley et al, 1984; Van der Merwe, 1991).

2.3 Odontometric measurement techniques

Mesio-distal measurements of teeth can be done directly in the mouth, on the dental casts and/or on radiographs in order to determine tooth sizes of either erupted teeth and/or unerupted teeth. However, both the dental casts and the radiographs need to be of very high quality.

Hunter and Priest (1960) found that teeth measured on dental casts were slightly larger than those measured directly in the mouth. They further compared soaped and unsoaped models, and found the soaped models to be slightly larger in overall dimensions. However, the consensus is that measurements from dental casts are more consistent and therefore more accurate than direct measurements taken from the mouth, particularly in the posterior segments where measurement becomes cumbersome (Axelsson and Kirveskari, 1983; Zilberman et al., 2003). Although, only a few investigators have used models poured in dental stone, most studies have failed to show any significant differences between the sizes of duplicate stone and plaster models (Doris et al., 1981; Axelsson and Kirveskari, 1983).

There are basically two methods of measuring teeth:

i) The sliding callipers with a vernier scale and

ii) A pair of engineer dividers in conjunction with a millimetre rule. Presently, most odontometric studies employ the former method (Lysell and Myrberg, 1982), which is also available with a digital micrometer and/or computer connections (Zilberman et al., 2003). Hunter and Priest (1960) found the sliding callipers to be more accurate, while the dividers gave consistently higher mean readings. Several other investigators have confirmed that the measure of mesio-distal tooth size is a highly repeatable measure (Doris et al., 1981; Zilberman et al., 2003). More recently, Zilberman et al. (2003) demonstrated that measurement with digital calipers on plaster models produced the most accurate and reproducible results and recommended it as the most suitable instrument for scientific work.

2.4 Tooth size predictions from radiographs

It is apparent that, before Nance (1947) proposed the measurement of the mesio-distal widths of unerupted tooth from an individual's radiographs, clinicians probably relied mainly on the averages of mesio-distal tooth widths published by Dr. G.V. Black (Black, 1902). Black (1902) did not indicate the population from which the data were derived. Therefore, the use of these average mesio-distal tooth sizes could not be justified with the evidence of tooth size variations within individuals and population groups. The accuracy of mesio-distal tooth width measurements from radiographic film depends on many radiographic factors such as target-film distance (Bull, 1959), absence of distortion in the films and the clarity of the crown outline (Ballard, 1944). Overlapping in the film may be observed at the contact points of radiographed teeth if the central ray of the tube does not pass straight through them and this makes measurement difficulty and less reliable. Occasionally, the tooth to be measured is rotated in its crypt and this too presents difficulty in obtaining accurate mesio-distal tooth width measurements. Furthermore, as Foster and Wylie (1958) contended, it is more reliable to use the direct measurements of the erupted teeth than rely upon measurements made from intraoral radiographs of dubious quality. Cohen (1959) described a radiographic measurement method that incorporated a correction factor for enlargement. The sum of the radiographic widths of the canine and premolars is multiplied by the correction factor to obtain an estimate of the sum of the true widths of these teeth. Various other procedures have been used that are based on the basis that the degree of magnification on a given film is approximately the same for a primary or permanent tooth as for its adjacent unerupted permanent tooth (Huckaba, 1964; Sim, 1972). Staley et al. (1984) came up with simple linear regression equations to predict the combined mesio-distal widths of unerupted permanent canines, first and second premolars, that incorporated mesio-distal tooth widths obtained from periapical radiographs. Although these equations demonstrated low standard errors of estimates, they too had the disadvantages of predictions associated with radiographic images.

2.5 Tooth size predictions from erupted teeth on casts

The widely used methods to predict the sum of the unerupted permanent canines and premolars depend upon the statistical correlation of the sum of permanent four permanent mandibular incisors and the sum of the canines and premolars (Ballard and Wylie, 1947; Carey, 1949; Tanaka and

Johnston, 1974; Moyers, 1958, 1973, 1988). Ballard and Wylie (1947) established the first regression equations. They developed the following formula despite a low correlation (r= 0.64):

$$Y=9.41+0.527X$$

where Y is equal to the sum of permanent canines and premolars, while X is equal to the sum of mesio-distal widths of the mandibular incisors.

Ballard and Wylie (1947) came to the conclusion that their method had only 2.6 per cent error (0.6 mm) as compared to a 10.5 per cent error (2.2 mm) when using radiographs only. Therefore, they suggested the use of their method as an adjunct to Nance's (1947) method.

Several studies on prediction methods based upon the measurement of the mesio-distal widths of permanent mandibular incisors have reported low to moderate correlations (Ballard and Wylie, 1947, Moyers, 1973, 1988; Tanaka and Johnston, 1974). Huckaba (1964) stated that human teeth tend to show a closer correlation in proportionate size while demonstrating the use of Moyers' original prediction charts (Moyers, 1958). The correlation coefficient obtained by Tanaka and Johnston (1974) are r= 0.648 for mandibular and r= 0.625 for maxillary teeth. There have been even greater variations of these correlation coefficients in the findings of different studies when these methods are applied in specific non-Caucasian groups (Motokawa et al., 1987; Frankel and Benz, 1986; Al-Khadra, 1993; Hattab et al., 1996; Schirmer and Wiltshire, 1997; Lee-Chan et al., 1998; Jaroontham and Godfrey, 2000).

Despite these low to moderate correlations some advantages exist in their clinical use. The location of the four permanent mandibular incisors in the midst of the space management problems not only offers one of the advantages in their use in predicting the unerupted tooth sizes of the canines and premolars but also easy accessibility for accurate measurement both in the mouth and on the dental casts (Moyers, 1988). Furthermore, the mandibular incisors erupt early in the mixed dentition and have very low variability in shape and size (Moyers, 1988). It is also claimed that with the eruption of the first permanent molars and mandibular incisors, most of the expected growth in the mandibular arch has been accomplished (Sillman, 1964).

The Moyers analysis used the sum of the widths of the mandibular incisors to predict the sum of both mandibular and maxillary canines and premolars at various probability levels (5% to 95%), initially as combined tables for both sexes (Moyers, 1973), and later as separate tables (Appendix III) for either sex (Moyers, 1988). Neither the sample nor the regression equations upon which Moyers (1958, 1973, 1988) tables are based have been described in the literature. However, he recommended its use at 75% probability level, which clinically, is thought to give protection on the crowded side. Although of questionable reliability, Moyers (1988) and Tanaka and Johnston (1974) are still widely accepted because they do not require radiographs and are simple and quick to perform. They are, arguably, more readily applied by a spectrum of clinicians (Runey et al., 1978; Al-Khadra, 1993; Irwin et al., 1995; Yuen et al., 1998). Tanaka and Johnston (1974) also used the sum of the mesio-distal widths of the mandibular central and lateral incisors to develop regression equations in predicting the sizes of the unerupted canines and premolars. They established that the mesio-distal widths at the seventy-fifth percentile level can be predicted by taking one half the width of the mandibular incisors and adding 10.5 mm for the mandibular teeth and 11.0 mm for the maxillary teeth (Appendix V). Of the common methods employed today, this is perhaps one of the quickest and easiest. However, the standard errors of estimates for the correlations were rather high (0.86 mm for the maxillary and 0.85 mm for the mandibular teeth) (Irwin et al., 1995). More recently Nourallah et al. (2002) found higher correlation of the two permanent mandibular incisors and two permanent maxillary first molars and suggested their use in the new prediction tables and regression equations for a Syrian population.

Some studies have shown that the correlation between mesio-distal widths of teeth measured on casts are too weak to be of any practical value for prediction (Moorrees and Reed, 1964, Arya et al., 1974, Ingervall and Lannartsson, 1978), while others have found some clinical advantages, despite their low to moderate correlations (Moyers, 1973, 1988; Tanaka and Johnston, 1974; Bishara and Jakobsen, 1998; Nourallah et al., 2002). Moyers (1973) claimed that, from measurement of mandibular incisors on dental casts alone, 95% of patients have a combined mesio-distal width of canines and premolars within 1 mm of the predicted value in his table, which should be clinically acceptable. Several other predictors have been studied, however, these also showed moderate correlation coefficients with combined mesio-distal width of unerupted permanent canines, first and second premolars (Ballard and Wylie, 1947; Van der Merwe et al., 1991; Nourallah et al., 2002). It has been shown that the correlation between deciduous and permanent teeth is weaker than that between the mesio-distal widths of permanent teeth (Moorrees et al., 1957; Hixon and Oldfather, 1958; Moorrees and Chadha, 1962; Moorrees and Reed, 1964; Lysell and Myrberg, 1982). For instance, the sum of maxillary deciduous canine and molar widths was moderately correlated (r= 0.50 in the maxilla and r= 0.57 in the mandible) to the sum of the permanent canine and premolars (Moorrees and Reed, 1964). Bishara and Jakobsen (1998) compared Tanaka and Johnston (1974) with Boston University prediction approach on a study of records from 55 individuals obtained from Iowa longitudinal growth study and found that the two non-radiographic methods were fairly comparable but not as accurate as radiographic methods. The Boston University approach is based on adding the sum of mesio-distal widths of the mandibular deciduous canines and twice the width of the first deciduous molars. Bishara and Jakobsen (1998) demonstrated that the standard errors of estimates were fairly comparable and, therefore, the Boston University method can be quite useful in cases where permanent teeth have not erupted.

Recently several studies have been conducted to evaluate the applicability of the Tanaka and Johnston (1974) and Moyers (1988) methods in non-Caucasian groups [Schirmer and Wiltshire (1997), for Black South Africans; Yuen et al. (1998), for Chinese; Lee-Chan et al. (1998), for Asian-Americans; Jaroontham and Godfrey (2000) for Thai population; Nourallah et al. (2002) for Syrians; Diagne et al. (2003) for Senegalese]. Only two of these studies have been conducted for the Black South Africans (Schirmer and Wiltshire, 1997; Diagne et al., 2003). Therefore, more studies are still needed to evaluate the applicability of these two prediction methods in other African populations.

2.6 Predictions from combination of radiograph and cast measurements

Some methods of prediction have used both radiographs and the sizes of erupted teeth (Hixon and Oldfather, 1958; Stahle, 1959). This combines the best features of both techniques in an effort to improve predictability and yet sacrifices time saving features. The quality of intraoral films should be the determining factor in the selection of the technique over the other. As Fosters and Wylie (1958) pointed out predictions based on erupted incisors are more accurate than those using poor intraoral films, while the accuracy achieved with films taken by a meticulous technique can outperform the mathematical formulas. In combining measurements from casts and radiographs, Hixon and Oldfather (1958) added the maximum mesio-distal diameters of the permanent mandibular central and lateral incisors with those of the unerupted premolars measured on the intraoral periapical film. The summation is called the "measured value," which is used to determine the "estimated value" from prediction charts. The prediction charts compensate for magnification inherent in radiography and are valid only for measurements taken from radiographs from a long-cone (16 inch) x-ray unit. The method is claimed to be accurate to within 0.6 mm for 68 percent of the cases, 1.1 mm for 95 percent of the cases, and 1.7 mm for 99 percent of the cases. It is important to note that Hixon and Oldfather (1958) method was only for prediction of the sum of the mandibular canines and premolars (r= 0.88). It is apparent that their method has not found wide use in clinical practice despite the low standard error of estimate (0.6 mm) that was found. Furthermore, it has been reported that the original Hixon and Oldfather (1958), on the average, underpredicted the mesio-distal widths of canine and premolars (Moyers, 1973; Kaplan et al., 1977; Gardner, 1979). The modifications to the original Hixon and Oldfather (1958) improved its predictive value (Staley and Kerber, 1980; Staley et al., 1979; 1983; Bishara and Staley, 1984), particularly when separate equations were used for males and females from the same Iowa Facial growth study subjects (Staley et al., 1979). The revised equations resulted in a lower standard error of estimate as compared to the original equation (Staley and Kerber, 1980). Ingervall and Lennartson (1978) showed that predictions were more accurate for the mandibular than maxillary teeth.

2.7 Comparisons of the prediction techniques

Prediction methods developed in the last half of the 20th century have been compared in some studies. These methods that were compared included those derived from simple regression analysis, multiple regression analysis and other approaches either based on measurements from radiographs or dental casts. Most of these studies have concluded that measurements of the unerupted teeth on radiographs were the best for determining their true mesio-distal widths (Kaplan et al., 1977; Zilberman et al., 1977; White, 1978; Staley and Hoag, 1978; Ingervall and Lannartsson, 1978, Staley et al., 1979; de Paula et al., 1995). However, when Foster and Wylie (1958) compared estimation of mesio-distal widths of the unerupted permanent canines, first and second premolars from Ballard and Wylie (1947) prediction method and radiographic method with same teeth after eruption, both methods showed inaccuracies in a sample of 14 children. These inaccuracies ranged from overestimates of 3.9 mm and 4.0 mm and underestimates of 5.7 mm and 1.6 mm by Ballard and Wylie (1947) and radiographic methods respectively. The analyses, which treat the sexes separately, have been reported to be better predictors than those methods that do not discriminate between the sexes (Staley et al., 1979). However, the Hixon and Oldfather (1958) prediction did not appear to be seriously influenced by sex.

Kaplan et al. (1977) compared the accuracy of the Hixon and Oldfather (1958), Moyers (1973), and Tanaka and Johnston (1974) mixed dentition analyses. They proposed a modification of the Hixon-Oldfather (1958) equation wherein the width of the mandibular lateral incisor was not used.

The other three values were added to yield a value in close approximation to the combined widths of the canine and premolars. Computed values are then added to the predicted values to improve the accuracy. It should be noted that their equation was based on the use of a 19-inch target-skin distance, rather than the standard 16-inch long-cone distance. They concluded that the Hixon and Oldfather analysis was the most accurate of the three methods for predicting the size of the unerupted permanent canines and premolars. Zilberman et al. (1977) checked the accuracy of the Moyers (1973) and Hixon-Oldfather (1958) estimations in a group of forty-six Israeli children. They found a stronger correlation in both arches between observed sizes and measurements from the radiographs than from the Moyers' tables (Moyers, 1973). The scatter around the regression line based on Moyers' (1973) estimate was larger than that around the regression line based on radiographic findings. Their study also indicated that the combination method developed by Hixon and Oldfather (1958) was comparable in accuracy to the strictly radiograph measurement technique.

Smith et al. (1979) checked the accuracy of the analysis based on Moyers' (1973) tables, Hixon and Oldfather's (1958) combination procedure, and their Tri-4 analysis. They concluded that the Tri-4 analysis appeared to be simpler and a more accurate method for mixed dentition analysis than those in common use at that time. However, Gardner (1979) found that Nance (1947), Moyers (1973) and Tanaka and Johnston (1974) tended to overpredict by 1 to 3 mm, while the Hixon and Oldfather (1958) was more likely to underpredict by about 0.5 mm.

Motokawa et al. (1987) compared four nonradiographic techniques in Japanese children and found the correlation between the mandibular permanent incisors and permanent canines and premolars were relatively low compared with those of earlier investigations. The difference may be attributed to racial variability. However, they indicated that their interlateral incisor width (I. L. I. W.) analysis was more accurate method, in addition to being simpler and quicker.

De Paula et al. (1995) investigated the accuracy of the use of measurement of the mandibular canines and premolars directly on the 45° cephalometric radiographs on forty Brazilian children. They found that there were significant differences between the actual values of mandibular canines and premolars at one percent level in both boys and girls probably due to magnification factor inherent to their radiographic technique (7.3 % for boys and 8.5 % for girls). However, when compared with Moyers (1988) at 75 %, Tanaka and Johnston (1974), Carey (1949), and Ballard and Wylie (1947), their prediction method still produced better correlations with the actual values of canines and premolars (r= 0.821 for boys and r= 0.73 for girls).

Most of these studies (Hixon and Oldfather, 1958; Kaplan et al., 1977; Zilberman et al., 1977; White, 1978; Staley and Hoag, 1978; Ingervall and Lannartsson, 1978, Staley et al., 1979; de Paula et al., 1995) have shown that the predicted values from measurements of radiographs were closer to the actual width of the permanent canine and premolars. On the other hand, only fair correlation for the mesio-distal dimensions of the four mandibular permanent incisors as a basis for predicting the widths of permanent canines and premolars have been found. Correlations between the mandibular permanent incisors and the permanent canines and premolars were found to be relatively low (ranging from r= 0.625 to r=-0.69 - Ballard and Wylie, 1947; Hixon and Oldfather, 1958; Tanaka and Johnston, 1974).

2.8 Estimation of tooth size in black populations

Regression equations used for predicting the size of unerupted teeth are based on genetic inheritance of the tooth size. That permanent tooth sizes do vary among different races is, undoubtedly, a proven fact (Bailit, 1975; Richardson and Malhotra, 1975; Bishara et al., 1986, 1989; Merz et al., 1991; Hattab et al., 1996; Otuyemi and Noar, 1996). Few studies have demonstrated that the teeth of permanent dentition are larger in Negro Americans than Caucasians (Richardson and Malhotra, 1975; Ferguson et al., 1978; Merz et al., 1991). Ferguson et al. (1978) conducted a study in 105 Negro individuals ranging from 10 to 18 years of age and found that the mean total mesio-distal widths of tooth groups measured were slightly larger than those from a study by Tanaka and Johnston (1974). Although their correlation coefficients approximately paralleled the findings of Hixon and Oldfather (1958) for the mandible (r= 0.69), and Tanaka and Johnston for the maxilla (r= 0.63), there were differences between their regression constants and the results of their study:

$Y=11.9830+0.4493X$ for the maxilla, and

$Y=9.9350+0.5288X$ for the mandible, where Y is the predicted sum of permanent canine, first and second premolars, whereas X equals to the sum of measured four permanent mandibular incisors.

Even fewer studies have compared the mesio-distal tooth widths of African Blacks with Caucasian samples. Turner and Richardson (1989) observed significant differences in mesio-distal tooth widths in Kenyan and Irish populations. A study by Otuyemi and Noar (1996) compared mesio-distal tooth widths of Nigerian children to a matched British sample and found the mesio-distal crown dimensions of Nigerian sample were significantly larger than the British counterparts. It is argued that the prediction data from African Americans might not accurately represent what would be found in African blacks since American are a genetic admixture of people from Africa, England, Ireland, Germany, and many parts of the Caribbean (Otuyemi and Noar, 1996).

There are probably large differences in tooth size among subgroups of blacks and using one set of standards for blacks on all other black population groups could lead to serious clinical errors (Bailit, 1975; Irwin et al., 1995). Only two reported studies have investigated the applicability of non-radiographic prediction methods on black subjects of African descent (Schirmer and Wiltshire, 1997; Diagne et al., 2003). Schirmer and Wiltshire (1997) found in their study of 100 black South Africans that there were highly significant differences between the sum of mesio-distal widths of permanent canines and premolars of the black subjects and those of Moyers prediction tables (1988) at all probability levels, except in the maxilla for females at 75%, 85% and 95% probability levels. They, therefore, concluded that Moyers method (1988) might not be appropriately used for black patients of African descent, due to racial and ethnic diversity. Diagne et al. (2003), similarly, concluded that both Moyers at 50% probability level and Tanaka and Johnston (1974) do not accurately predict the mesio-distal widths of unerupted permanent canine, first and second premolars in Senegalese children. However, their sample size of 50 black subjects may not have been representative enough to enable such conclusion.

Regardless of the prediction method used, one has to assume that the most accurate equations for prediction of tooth size should be based on accurate measurements obtained on the population in question, but such equations are not presently available on Kenyan population. Since there is no existing data or guidelines for predicting tooth sizes in a Kenyan situation, the mesio-distal tooth widths of the fully erupted permanent canines and premolars were used to evaluate the applicability of these two non-radiographic methods (Tanaka and Johnston, 1974; Moyers, 1988) in a Kenyan sample. In this study, the sums of measured mesio-distal widths of four permanent mandibular incisors were treated as independent variable and the sum of mesio-distal widths of canine; first and second premolars from the actual measurements and predictions would be treated as dependent variables. Furthermore, the sum of the measured mesio-distal widths of canines and premolars was assumed to be the "gold standard" upon which the comparisons were made.

CHAPTER III

AIM AND OBJECTIVES

3 AIM AND OBJECTIVES

The aim of this study was to evaluate the applicability of the Tanaka and Johnston (1974) and the Moyers (1988) methods of predicting the size of permanent canines and premolars in a Kenyan Sample.

Objectives

1) To calculate the mesio-distal widths of the permanent canines and premolars from Tanaka and Johnston equation (Tanaka and Johnston, 1974) and the Moyers prediction tables (Moyers, 1988) in the Kenyan sample.

2) To compare the predicted values of mesio-distal widths of the permanent canine and premolars from each of these methods with the measured values

3) To compare the predicted values of mesio-distal widths of permanent canines and premolars from Tanaka and Johnston (1974) with those from Moyers method (1988).

CHAPTER IV

METHODOLOGY

4 METHODOLOGY

4.1 Sample size determination

In such a study where various parameters of variability have not been previously determined (Phillips, 2002), several assumptions had to be made in the determination of the sample size for this study of a Kenyan population.

According to the aims and objectives of this study, *precision* levels were calculated at 95% confidence level. Precision refers to the range or interval of values that enclose the true population mean when it is estimated from statistics (Petrie et al., 2002; Bowling, 2003). In consultation with a statistician we had to make following assumptions in order to have statistical power of at least 80%.

Assumptions

i) Confidence level of 95% [that is, 95% confidence interval means that there is 95% chance that the interval will include the true (but unknown) population effect of the intervention], and confidence interval at 0.2 mm (sum of the measured mesio-distal widths of permanent canine, first and second premolars).

ii) The clinically important difference is assumed to be the standard error of the mean of 0.2 mm (Richardson and Malhotra, 1975; Smith et al., 1979; Bishara et al., 1989).

iii) The standard deviation of the differences of 0.85 mm for mandibular arch was derived from pilot study and found to be comparable to previous studies elsewhere (Wangpichit et al., 2001).

iv) The measured variables were roughly "normally distributed" (Altman, 1982).

In spite of the above considerations in the sample size determination we also considered time and financial constraints (Rosner, 1990), and arrived at a minimum of 120 patients for the study, worked out as follows:

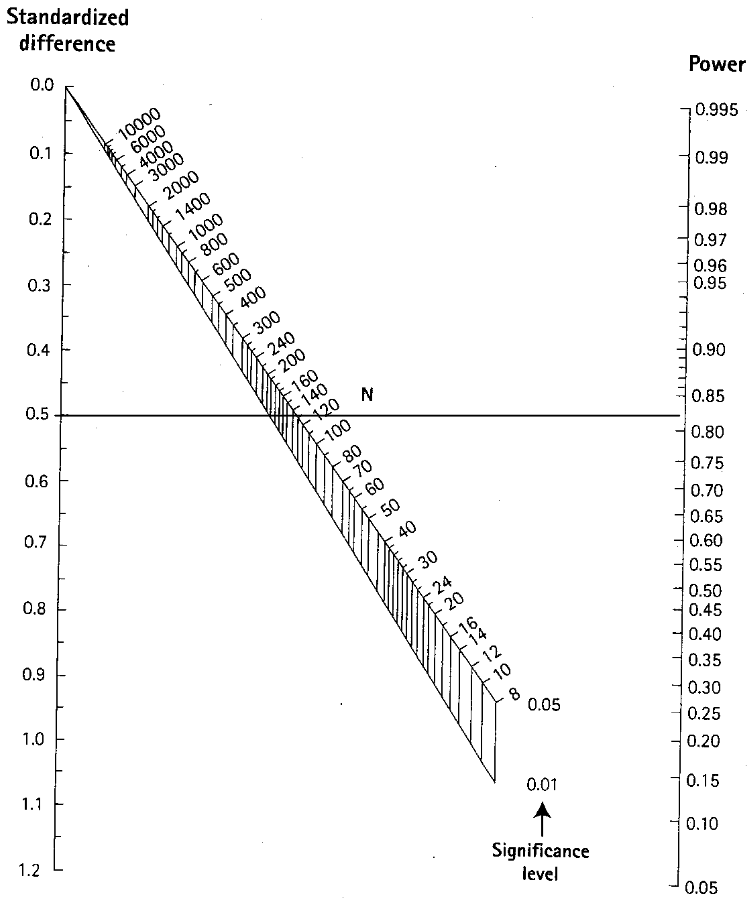

Figure 4.1; Altman's (1982) monograph for the calculation of sample size or power

The standard difference is derived from the equation below:

$$2\delta/\sigma d = 0.4/0.85 = 0.471$$

where δ is the clinically important difference (0.2 mm according to Richardson et al, 1975; Bishara et al, 1989).

σd is the standard deviation of the differences (0.85 mm for mandibular teeth from by pilot study and confirmed by Wangpichit et al. (2001).

Given the above assumptions, a line was drawn joining the standardized difference of approximately 0.5 to the power of 80% and the sample size (N) was read at 5% significance level, which gave N equals to 130 subjects (Figure 4.1).

4.2 Ethical Considerations

Ethical clearance was obtained from Ethics and Research Committees of both the University of the Western Cape and Kenyatta National Hospital, Nairobi (Appendix I). The parents of the participating children and/or patients were informed appropriately in writing and gave informed consent by signing the consent form (Appendix II). Only patients with informed consents were entered into the study.

4.3 Study sample

One hundred and thirty-one sets of dental casts were obtained from patients attending Orthodontics Clinic of the Kenyatta National Hospital. It is currently the only public health facility offering orthodontic services in Kenya. Therefore, Kenyatta National Hospital receives most of the patient referrals for orthodontic care.

Mixed dentition space analysis is employed in the treatment planning of the mixed dentition where not all the permanent canines and premolars are present in the mouth. However, this study included only subjects with presence of permanent teeth in order to test the applicability of the Moyers (1988) and Tanaka and Johnston (1974) methods of prediction.

A maximum age of 21 years had to be set as an upper age limit since it has been reported that beyond 21 years individual's teeth may be reduced significantly by interproximal attrition (Wangpichit et al., 2001) and this could bias the results of the study.

A modified random sampling technique was used, where new patients with odd registration numbers from the daily patient register were selected and consecutive ones meeting the set inclusion criteria were further selected for this study. Although, the use of patient registers is not usually very accurate (Bowling, 2003), it was assumed that it was capable of eliminating the effect of both deliberate and unconscious biases. The informed consent was obtained for each of the patients before accurate alginate impressions of both maxillary and mandibular dentitions were taken and immediately casted in dental stone to prevent dimensional changes.

Inclusion Criteria

i) Indigenous Black patients of Kenyan descent with fully erupted permanent incisors, permanent canines, and premolars in both maxillary and mandibular arches.

ii) The patients had to be free of any systemic disease or serious health problems

iii) Patients with teeth free from restorations, proximal wear, fractures or proximal caries as determined by clinical examination.

iv) Patients with teeth free from any Hypoplasia or other dental anomalies.

v) A maximum age of 21 years to preclude any discrepancies due to significant proximal wear (Doris et al., 1981; Wangpichit et al., 2001).

vi) High quality dental study casts free from any distortions.

4.4 Impression procedure

Standard orthodontic trays were used for impression taking. The alginate impression material was mixed according to the manufacturer's recommendations. A mix of alginate impression material (Blueprint™ cremix) was placed into the trays, and the impressions were taken in the usual manner.

4.5 Pouring technique

The impressions were poured in dental stone, which has small (0.08%) expansion factor (Phillips, 1984; Zilberman et al., 2003). Trimming of the dental casts was not done, as the casting bases were adequate. Only two dental casts came out with broken teeth and new impressions from the same patients (after recall) had to be repeated in the usual manner.

4.6 Measurement of mesio-distal tooth widths

A set of both maxillary and mandibular study casts from each patient was serialized and names kept anonymous.

A vernier gauge calibrated with digital micrometer (*Mitutoyo™, Japan*), whose measuring beaks were sharpened, was used to measure the mesio-distal widths of the individual teeth from unsoaped study casts. All the teeth from left second premolar through to the right second premolar of each set of dental casts were measured to the nearest 0.01 mm. Mesio-distal width is measured between two anatomical contact points of each tooth parallel to the occlusal surface of the teeth and also parallel to the vestibular surface of the model (Figure 4.2). When a tooth was rotated or malposed in relation to the dental arch, the measurement was taken between the points on the approximate surface of the crown, where it was judged that normal contact should have occurred with the neighbouring tooth (Ghose and Baghdady, 1979). All the measurements were recorded to 0.01 mm, and entered on excel spreadsheet (Appendix IVa and IVb).

Figure 4.2; Tooth measurement procedure for a selected case

The researcher was calibrated by one of the supervisors in the Department of Orthodontics of the University of the Western Cape, on 10 sets of the study casts. Intra-observer variability was obtained by measuring 10 sets of randomly selected dental casts twice at one-week interval. The second measurements were done by the investigator, but recorded by an assistant so as to prevent bias. Subsequent measurements were done only once to simulate the real practice situations.

The sum of the four mandibular incisors was determined for each patient. Left–right tooth size correlations are extremely high for individual teeth (average r = 0.9) and even higher if all the teeth in a quadrant are summated (Garn, 1977). Because high bilateral symmetry in the mesio-distal width of canines and premolars have been documented in the literature (Garn, 1977; Staley et al., 1979; Keene, 1979; Wangpichit et al., 2001), the sum of the following groups of teeth were be pooled and the mean mesio-distal tooth width calculated for each sex, and the whole sample:

i) the four mandibular incisors
ii) the mandibular canines and premolars per quadrant
iii) the maxillary canines and premolars per quadrant.

4.7 Prediction of mesio-distal widths of canines and premolars

The sum of the four permanent mandibular incisors were used to predict the combined sizes of the permanent unerupted canines and premolars using both Moyers Method (1988), and Tanaka and Johnston (1974).

4.8 Null Hypothesis

There is no difference between the sums of measured mesio-distal widths of permanent canine, first and second premolars in one quadrant of either mandibular or maxillary arch, and their predicted values derived from Moyers (1988) and Tanaka and Johnston (1974) methods.

4.9 Data analysis

Two-tailed significance tests were used and statistical significant differences was achieved only if the P-value was less than significance level of 0.05 and this was then said to be significant at the 5% confidence level (Petrie et al., 2002a; Pallant, 2003; Bowling, 2003). A mean difference of zero is needed for an unbiased accurate prediction.

i) Computer software, SPSS (Version 11.0) whose basic aspects have been described by Pallant (2003), was used to analyse the statistical data obtained from this study.

ii) Errors of measurement were statistically assessed using Dahlberg's formula (Dahlberg, 1940):

$$\text{Method error} = \sqrt{\Sigma d^2/2n}$$

where d is the differences between duplicate measurements; n is the number of double measurements.

iii) Sum of the four mandibular incisors was calculated

iv) Sum of mesio-distal tooth widths of canines, first premolars and second premolars from both mandibular and maxillary arches were obtained per quadrant and a mean mesio-distal width calculated for each category.

v) Sum of predicted mesio-distal widths of canines, first and second premolars was determined using the sum of the four mandibular incisors according to both Tanaka and Johnston (1974), and Moyers (1988) methods.

vi) The data were explored for "Normality" particularly the sum of four mandibular incisors and sum of canines and premolars for each quadrant, by use of Kolmogorow-Smirnov test ($p>0.05$) in SPSS (Version 11.0).

vii) Comparison of the predicted mesio-distal widths of the permanent canines, premolars from each method with the actual value paired t test and graphical methods.

viii) Comparison of the predicted mesio-distal tooth widths from Tanaka and Johnston (1974) with those from Moyers Method (1988) using paired t test and graphical methods.

4.10 Statistical analysis

The following statistical techniques were employed:

i) The data from the Kenyan sample were explored to examine normality of the data using Kolmogorow-Smirnov test ($p>0.05$) in SPSS (Version 11.0).

ii) Two-tailed paired t-tests were performed to examine bilateral symmetry of mesio-distal widths of all measured individual teeth and combined mesio-distal widths of permanent canines, first and second premolars of each arch.

iii) Pearson product-moment coefficients were used to evaluate the correlation between the groups of teeth.

iv) Independent t-test was performed to compare data from male to that of female subjects.

v) Paired t test were used to test the significance of the difference between the predicted and measured ("actual") values for each method as well as to test for differences between the two methods.

vi) A simple regression analysis of the dependent variable (the mean sum of the mesio-distal widths of the permanent canines first and second premolars) was performed with independent variables (mean sum of four mandibular incisors) to devise a regression a possible equation for the Kenyan sample.

A large number of t tests were performed, but in order to reduce the possibility of the chance of some t-test achieving significance due to chance alone, Benforroni correction was necessary.

CHAPTER V

RESULTS

5 RESULTS

5.1 Study Sample

A total of 131 sets of dental casts were obtained from 50 male and 81 female subjects, with a mean age of 15.8 years (SD; 3.4 years) and 14.9 years (SD; 3.4 years) respectively (Table 5.1).

Table 5.1; Age distribution of the Kenyan sample

Sex	**Mean± SD* (years)**	**Range (years)**
Male (n# = 50)	15.8±3.4	10.0 - 21.0
Female (n# =81)	14.9±3.4	9.0 - 21.0

*SD indicates standard deviation
#n is the sample size for each sex group

5.2 Errors of measurement

Method errors showed that differences between duplicate measurements ranged from 0.023 millimetres to 0.140 millimetres with averages of 0.080 millimetres and 0.044 millimetres in the mandibular and maxillary arches respectively (Table 5.2). These values compare favourably with those reported by other investigators (Moorrees et al., 1957; Kaplan et al., 1977; Keene, 1979; Buschang et al., 1988) and were acceptable for the study of tooth sizes (Yuen et al., 1997).

Table 5.2; Method error calculated by Dahlberg's formula (Dahlberg, 1940)

Tooth#	Arch	
	Mandibular (mm)	**Maxillary (mm)**
RPm2	0.053	0.061
LPm2	0.061	0.041
RPm1	0.094	0.035
LPm1	0.055	0.048
RC	0.094	0.061
LC	0.126	0.047
RLi	0.076	0.042
LLi	0.050	0.037
RCi	0.140	0.047
LCi	0.044	0.023
Average	**0.080**	**0.044**

#See the list of abbreviations for definitions, on page XIV.

5.3 Descriptive statistics for the sample

The means, ranges and standard deviations of the mesio-distal widths of individual measured teeth are presented for the combined sexes, male and female subjects (Tables 5.3). For male subjects, the mandibular incisors showed less variability in mesio-distal tooth size than the maxillary incisors. In the other teeth there were greater variability in the mandibular teeth than in the maxillary teeth. A similar pattern was also observed in the female group as well as the whole sample. This variability is depicted by the standard deviations of their mesio-distal tooth widths (Tables 5.3).

Table 5.3; Descriptive Statistics for mesio-distal widths in millimetres of individual teeth for the combined sexes, male and female subjects.

Tooth#	Sex	Mandibular (mm)			Maxillary (mm)		
		Mean	Range	SD*	Mean	Range	SD*
Pm2	M	7.70	6.41 - 9.01	0.58	6.99	6.07 - 8.80	0.51
	F	7.49	6.03 - 9.21	0.53	6.99	5.93 - 8.15	0.42
	M + F	7.57	6.03 - 9.21	0.55	7.08	5.93 - 8.80	0.47
Pm1	M	7.68	6.57 - 8.77	0.58	7.39	6.81 - 8.59	0.50
	F	7.41	6.58 - 8.40	0.42	7.39	5.94 - 8.24	0.39
	M + F	7.51	6.57 - 8.77	0.50	7.46	5.94 - 8.59	0.44
C	M	7.24	6.31 - 8.40	0.52	7.69	7.11 - 9.22	0.49
	F	6.83	6.01 - 7.77	0.40	7.69	6.83 - 8.70	0.37
	M + F	6.99	6.01 - 8.40	0.49	7.88	6.83 - 9.22	0.48
Li	M	6.13	5.33 - 7.47	0.46	7.03	6.02 - 8.56	0.58
	F	5.91	5.16 - 6.82	0.37	7.03	5.51 - 8.60	0.59
	M + F	6.00	5.16 - 7.47	0.42	7.14	5.51 - 8.60	0.60
Ci	M	5.62	4.86 - 6.54	0.37	8.76	7.92 -11.11	0.61
	F	5.41	4.43 - 6.48	0.37	8.76	7.36 -10.22	0.55
	M + F	5.49	4.43 - 6.54	0.38	8.92	7.36 -11.11	0.60

#Pm2 indicates second premolars; Pm1, first premolar; C, Canines; Li, Lateral incisors; Ci, central incisors.

*SD represents standard deviation.

5.4 Bilateral symmetry

The paired t-test was used to compare left and right individual mesio-distal tooth width differences for the whole sample (N=131) because normality of the data was confirmed by Kolmogorow-Smirnov test ($p>0.05$). Furthermore, with a sample size greater than 30, violation of assumption of normality is unlikely to cause any problems (Pallant, 2003). Absolute mean differences between the left and right mesio-distal widths of any individual tooth ranged from 0 to 0.04 millimetres (Table 5.4). Only mandibular lateral incisors, maxillary canines and first premolars showed statistically significant bilateral differences of 0.04 millimetres ($p < 0.05$) with standard deviations of 0.16 millimetres, 0.18 millimetres and 0.19 millimetres respectively. But, when Bonferroni correction was applied ($p<0.005$), no statistically significant bilateral differences between them were observed (Table 5.4).

Table 5.4; Left and right comparisons of mesio-distal widths for individual teeth of whole sample (N=131).

Tooth $	**Mandibular**					**Maxillary**				
	Mean*	**SD***	**t***	**df***	**P#**	**Mean***	**SD***	**t***	**df***	**P#**
Pm2	0.028	0.234	-1.37	130	0.173	0.015	0.240	-0.76	130	0.452
Pm1	0.018	0.197	-1.05	130	0.294	0.044	0.191	-2.67	130	0.009
C	0.010	0.180	0.64	130	0.524	0.044	0.184	2.73	130	0.007
Li	0.039	0.164	-2.73	130	0.007	0.005	0.270	0.20	130	0.844
Ci	0.002	0.134	-0.17	130	0.860	0.023	0.291	0.92	130	0.359

$Pm2 indicates second premolars; Pm1, first premolar; C, Canines; Li, Lateral incisors; Ci, central incisors.

*Mean represents absolute mean (without positive or negative sign); SD, standard deviation; t, the t-value; df, degree of freedom.

#P value, P<0.05; Significance level with Bonferroni correction, P< 0.005.

When combined mesio-distal widths of permanent canines, first and second premolars of either side of each dental arch were compared, there were no statistically significant differences between left and right (mandible, *p*=0.274 and maxilla, *p*=0.657) (Table 5.5).

These findings indicate that the right or the left side measurements, for both sexes, could be taken to represent the mesio-distal tooth widths for this sample. However, the averaged values of right and left sides of each jaw were used for further statistical analyses (Moorrees and Reed, 1964; Lee-Chan et al., 1998).

Table 5.5; Left and right comparisons of the sum of mesio-distal widths of permanent canines, first and second premolars for the whole sample (N=131).

Groups of teeth	Absolute Mean	SD*¤	t*	df*	P value#
Mandibular Σ 3, 4 & 5	0.036	0.376	-1.098	130	0.274
Maxillary Σ 3, 4 & 5	0.016	0.418	-0.445	130	0.657

* SD represents standard deviation; t, the t-value; df, degree of freedom.
#P value, P<0.05

5.5 Sex comparisons of mesio-distal tooth widths

For each tooth class, statistical analysis of the data was based on the average of mesio-distal widths of teeth on the left and right side of the dental arch since significant bilateral asymmetry has not been demonstrated in this present data (Tables 5.4 and 5.5). Since Moyers (1988) prediction tables were presented according to sex, it was important to determine in advance whether the mesio-distal tooth widths of male and female vary in the present data.

The results of independent t-tests presented in Tables 5.6 show that the mean mesio-distal tooth widths of the male subjects were consistently larger than females in both mandibular and maxillary dental arches respectively. All mean differences were statistically significant at $p< 0.05$ for mandibular and maxillary teeth, except mandibular second premolars (p=0.029). However, with Bonferroni correction (p<0.005) the mean mesio-distal widths of maxillary teeth failed to show statistically significant sex difference except those of maxillary first premolars (p=0.02) and lateral incisors (p=0.012). The most pronounced differences were shown by both maxillary (0.5±0.08 mm) and mandibular (0.4±0.08 mm) canines, and maxillary central incisors (0.4±0.10 mm), while maxillary first premolars (0.19±0.08) showed the least differences.

Table 5.6; Comparisons of mesio-distal widths of individual mandibular and maxillary teeth between male and female subjects.

Mandibular teeth	SEX	N*	Mean (mm)	SD* (mm)	P Value#	Mean Diff. (mm)	Std. Error Diff. (mm)
Mandible							
2nd Premolars	M	50	7.70	0.58	0.029**	0.218	0.098
	F	81	7.49	0.53			
1st Premolars	M	50	7.68	0.58	0.002	0.276	0.087
	F	81	7.41	0.42			
Canines	M	50	7.24	0.52	0.000	0.406	0.081
	F	81	6.83	0.40			
Lateral incisors	M	50	6.13	0.46	0.003	0.220	0.073
	F	81	5.91	0.37			
Central incisors	M	50	5.62	0.37	0.002	0.207	0.066
	F	81	5.41	0.37			
Maxilla							
2nd Premolars	M	50	7.22	0.51	0.006	0.231	0.083
	F	81	6.99	0.42			
1st Premolars	M	50	7.58	0.50	0.020**	0.194	0.082
	F	81	7.39	0.39			
Canines	M	50	8.18	0.49	0.000	0.490	0.081
	F	81	7.69	0.37			
Lateral incisors	M	50	7.30	0.580	0.012**	0.270	0.105
	F	81	7.03	0.59			
Central incisors	M	50	9.16	0.61	0.000	0.394	0.103
	F	81	8.76	0.55			

*SD represents standard deviation; N, the sample size of each group.
#P value, $P<0.05$; **Not significant with Bonferroni correction ($p< 0.005$).

The determination of sex differences between groups of teeth was performed only for groups that were to be used as summary measures in the statistical evaluation of the two prediction methods. Table 5.7 shows that there are statistically significant sex differences between the sum of mesio-distal widths of mandibular incisors, and the sum of permanent canines and first and second premolars of both jaws. The sum mesio-distal width of the canine and premolar of the male subjects was significantly larger than that of the female subjects (mandible, p=0.001; maxilla, p=0.000).

Table 5.7; Comparisons of mesio-distal widths of groups of teeth between male and female subjects.

Sum of teeth	**Sex**	**Mean (mm)**	**SD* (mm)**	**Mean Difference ± SEM* (mm)**	**P value#**
Mandibular Incisors	M	23.50	1.55	0.85±0.26	0.001**
	F	22.65	1.40		
Mandibular Canines, first & second premolars	M	22.62	1.53	0.90±0.25	0.001**
	F	21.72	1.14		
Maxillary canines, first & second Premolars	M	22.98	1.30	0.92±0.21	0.000**
	F	22.06	0.98		

*SD represents standard deviation; n is the sample size of each group; SEM, standard error of the mean.
#P value, P<0.05; **Significant at Bonferroni correction (p< 0.02)

5.6 Comparisons of predicted and actual tooth size

Normality of distributions of groups of the measured teeth for the male and female groups was examined using the Kolmogorow-Smirnov test. Because all the p-values were greater than 0.05, and the distributions were reasonably normal, the two-tailed t-test was employed to compare the differences between the predicted mesio-distal values of the mean sum of unerupted permanent canines, first and second premolars. A large number of paired t-tests were performed, but in order to reduce the possibility of the chance of some paired t-test achieving significance due to chance alone, Bonferroni correction was used to determine the significance levels for the mean differences between the predicted and measured values.

The results of the paired t-test are presented in Tables 5.8 and 5.9 for the differences between the mean sums of the measured mesio-distal widths of canines, first and second premolars and the predicted values derived from Moyers (1988) and Tanaka and Johnston (1974) methods for the mandibular and maxillary arches, respectively, for male group. Highly statistically significant differences were observed between the measured values from this Kenyan sample and Moyers (1988) prediction probability tables at all percentage confidence levels except at 85% for both mandible (p=0.57) and maxilla (p=0.02); and also at 95% for the maxilla (p=0.42). Similarly, Tables 5.10 and 5.11 show high statistically significant differences between combined mesio-distal widths of permanent canines and the two premolars in these black female subjects and those of Moyers (1988) prediction method at all probability levels except at 85% in the mandible (p=0.14) and maxilla (p=0.32), respectively.

On the other hand, predicted values of the combined mesio-distal widths of canines and two premolars derived from Tanaka and Johnston (1974) failed to show high statistically significant differences for either separate or combined sexes (Tables 5.8-5.12).

Graphically, Figures 5.1 through 5.4 represent relative comparisons between the actual measurements from the Kenyan sample, the predictions derived from Tanaka and Johnston (1974), and Moyers (1988) at probability levels of 50%, 65%, 75%, 85% and 95% for mandibular and maxillary arches of male and female subjects respectively. Scattergrams in the preliminary analyses of the present data showed that Moyers (1988) predictions at 5% to 35% confidence levels did not compare closely with the measured values of combined mesio-distal widths of canines and the two premolars of both mandibular and maxillary arches for both sexes. These were, therefore, left out in the subsequent graphical comparisons.

From Figure 5.1, it can be observed that Moyers (1988) at 85% probability level only coincide with actual measured values of the sum of mesio-distal widths of mandibular permanent canines and premolars for the corresponding sum of mandibular incisors ranging between 22.5 millimetres and 23.5 millimetres for the male subjects. It slightly overestimates for the values below and underestimates for the values of mandibular incisors above this range. The Tanaka and Johnston (1974) prediction values follow closely the measured values upto approximately 23 millimetres of the mandibular incisors above which it increasingly underestimates actual measurements of the mandibular arch of the male subjects. For the maxillary arch in Figure 5.2, the actual measurements closely follow Moyers (1988) at 95 % probability level for a wider range (22.5-24.5 mm) of corresponding values of mandibular incisors, but the latter increasingly overestimate actual measurements for the higher values of mandibular incisors. In maxillary arch of the male subjects the Tanaka and Johnston

(1974) prediction slightly underestimates the measured values but increasingly become closer to the actual measurements for higher corresponding values of the mandibular incisors.

In the mandibular arch of the female group (Figure 5.3), Moyers (1988) at 85% probability level and Tanaka and Johnston (1974) predictions are fairly parallel to the mandibular equations from Kenyan sample for the full range of sum of the four mandibular incisors. For the maxillary arch (Figure 5.4) it is the Moyers at 95% probability level that shows some closeness to the actual measurements for the range of mandibular incisors between 22.5 millimetres and 24 millimetres, below and above which it tends to overestimate and underestimate respectively. Maxillary Tanaka and Johnston (1974) prediction is fairly parallel upto approximately 23 millimetres of mandibular incisors, above which it increasingly overestimates the value of the actual combined mesio-distal widths of permanent canines and premolars for female subjects.

Slight differences in the predicted mesio-distal widths of the mandibular canines and the premolars derived from the Tanaka and Johnston (1974) equation and that of the actual measurements from the Kenyan sample is observed from Figure 5.5. The slopes of the lines in the graph do coincide for the sum of the mandibular incisors in the range between 21 millimetres and 24 millimetres and becomes divergent below and above this range. For the values of the four mandibular incisors below 21 millimetres the Tanaka and Johnston (1974) equation slightly overestimates the combined mesio-distal widths of unerupted canines and the two premolars in each quadrant of the maxillary arch, and underestimates for those above 24 millimetres. There was no significant difference in the predicted mesio-distal widths of the maxillary canines and the premolars derived from the Tanaka and Johnston (1974) equation and that of the actual measurements from the

Kenyan sample (Figure 5.6). The slopes of the lines in the graph are coinciding for all the sizes of the four mandibular incisors.

Table 5.8; Comparison of the predicted and actual values of mesio-distal widths of mandibular permanent canines, first and second premolars for male subjects.

Prediction method‡	Measured ∑ 3,4 & 5 of mandibular arch				
	Mean Diff. (y-x)†	**SD* (mm)**	**t***	**df***	**P value#**
Moyers 5%	-3.27	1.17	-19.78	49	0.000
Moyers 15%	-2.56	1.17	-15.48	49	0.000
Moyers 25%	-2.11	1.17	-12.79	49	0.000
Moyers 35%	-1.77	1.17	-10.70	49	0.000
Moyers 50%	-1.32	1.17	-7.95	49	0.000
Moyers 65%	-0.86	1.17	-5.17	49	0.000
Moyers 75%	-0.52	1.18	-3.14	49	0.003**
Moyers 85%	-0.10	1.18	-0.58	49	0.566**
Moyers 95%	0.65	1.18	3.86	49	0.000
T/J	0.37	1.15	2.27	49	0.027**

‡Moyers 5%-95% represent probability levels of Moyers (1988) prediction; T/J is Tanaka and Johnston (1974) prediction method.
†Mean difference; where y= the predicted value and x=the measured value of the ∑ 3,4 & 5 in millimetres.
*SD represents standard deviation; t, the t value; df, degree of freedom.
#P value, P<0.05; **Not significant with Bonferroni correction (p<0.003).

Table 5.9; Comparison of the predicted and actual values of mesio-distal widths of maxillary permanent canines, first and second premolars for male subjects.

Prediction method‡	Measured ∑ 3,4 & 5 of mandibular arch				
	Mean Diff. (y-x)†	**SD* (mm)**	**t***	**df***	**P value#**
Moyers 5%	-2.68	1.13	-16.70	49	0.000
Moyers 15%	-2.16	1.13	-13.47	49	0.000
Moyers 25%	-1.86	1.13	-11.60	49	0.000
Moyers 35%	-1.60	1.13	-10.00	49	0.000
Moyers 50%	-1.27	1.13	-7.90	49	0.000
Moyers 65%	-0.95	1.13	-5.97	49	0.000
Moyers 75%	-0.70	1.13	-4.38	49	0.000
Moyers 85%	-0.40	1.13	-2.50	49	0.016**
Moyers 95%	0.13	1.13	0.823	49	0.415**
T/J	0.23	1.13	1.422	49	0.161**

‡ Moyers 5%-95% represent probability levels of Moyers (1988) prediction; T/J is Tanaka and Johnston (1974) prediction method.
†Mean difference; where y= the predicted value and x=the measured value of the ∑ 3,4 & 5 in millimetres.
*SD represents standard deviation; t, the t value; df, degree of freedom.
#P value, P<0.05; **Not significant with Bonferroni correction (<0.003).

Table 5.10; Comparison of the predicted and actual values of mesio-distal widths of mandibular permanent canines, first and second premolars for female group.

Prediction method‡	Measured ∑ 3,4 & 5 of mandibular arch				
	Mean Diff. (y-x)†	**SD* (mm)**	**t***	**df***	**P value#**
Moyers 5%	-3.34	0.74	40.82	80	0.000
Moyers 15%	-2.61	0.74	-31.84	80	0.000
Moyers 25%	-2.17	0.74	-26.57	80	0.000
Moyers 35%	-1.83	0.74	-22.35	80	0.000
Moyers 50%	-1.37	0.74	-16.68	80	0.000
Moyers 65%	-0.89	0.74	-10.86	80	0.000
Moyers 75%	-0.55	0.74	-6.63	80	0.000
Moyers 85%	-0.12	0.74	-1.48	80	0.142**
Moyers 95%	0.62	0.74	7.52	80	0.000
T/J	-0.10	0.74	-1.24	80	0.218**

‡Moyers 5%-95% represent probability levels of Moyers (1988) prediction; T/J is Tanaka and Johnston (1974) prediction method.
†Mean difference; where y= the predicted value and x=the measured value of the ∑ 3,4 & 5 in millimetres.
*SD represents standard deviation; t, the t value; df, degree of freedom.
#P value, $P<0.05$; **Not significant with Bonferroni correction, ($p<0.003$).

Table 5.11; Comparison of the predicted and actual values of mesio-distal widths of maxillary permanent canines, first and second premolars for female group.

Prediction method‡	Measured ∑ 3,4 & 5 of maxillary arch				
	Mean Diff. (y-x)†	**SD* (mm)**	**t***	**df***	**P value#**
Moyers 5%	-3.28	0.79	-37.49	80	0.000
Moyers 15%	-2.62	0.79	-29.95	80	0.000
Moyers 25%	-2.25	0.79	-25.59	80	0.000
Moyers 35%	-1.95	0.79	-22.17	80	0.000
Moyers 50%	-1.55	0.79	-17.61	80	0.000
Moyers 65%	-1.14	0.79	-12.94	80	0.000
Moyers 75%	-0.82	0.79	-9.39	80	0.000
Moyers 85%	-0.46	0.79	-5.25	80	0.000
Moyers 95%	0.19	0.79	2.18	80	0.032**
T/J	-0.26	0.78	-3.10	80	0.003**

‡Moyers 5%-95% represent probability levels of Moyers (1988) prediction; T/J is Tanaka and Johnston (1974) prediction method.
†Mean difference; where y= the predicted value and x=the measured value of the ∑ 3,4 & 5 in millimetres.
*SD represents standard deviation; t, the t value; df, degree of freedom.
#P value, P<0.05; **Not significant with Bonferroni correction, (p<0.003).

Table 5.12; Comparison of Tanaka and Johnston (1974) and measured value of the sum of mesio-distal widths of canines, first and second premolars for whole sample (n=131).

Prediction method	Measured ∑ 3,4 & 5				
	Differences		**N***	**r***	**P value#**
	Mean (y-x)†	SD*(mm)			
Tanaka and Johnston (1974)-mandible	0 .078	0.944	131	0.748	0.349**
Tanaka and Johnston (1974)-maxilla	-0.075	0.945	131	0.612	0.367**

†Mean difference; where y= the predicted value from Tanaka and Johnston (1974) and x=the measured value of the ∑ 3,4 & 5 in millimetres.
*SD represents standard deviation; N, sample size; r, Correlation coefficient
#P value, $P<0.05$; **Not significant with Bonferroni correction, $p< 0.025$.

5.7 Regressions equations for the Kenyan sample

The regression characteristics of the obtained prediction equations for the Kenyan sample are presented in Table 5.13. The accuracy of the prediction is often expressed as the standard error of the mean for the prediction equations. In this study the standard error of estimates (mean) ranged between 0.73 millimetres and 1.14 millimetres for male, female and combined groups. The Pearson product moment correlation coefficients (r) were all above 0.5 and can be put into clinical orthodontic use (Johnston, 2002) by constructing regression equations for the Kenyan sample. The regression coefficients do not differ significantly between either sex, and the combined sexes.

Table 5.13; Regression characteristics (Y=BX + A)# for Kenyan sample

Canine-Premolar Segment	**Sex**	**r***	**r²***	**Regression Coefficient**		**Std. Error of mean (mm)**
				A	**B**	
Maxillary Arch	M	0.50	0.25	13.19	0.42	1.14
	F	0.64	0.41	11.94	0.45	0.76
	M + F	0.61	0.37	11.33	0.48	0.95
Mandibular Arch	M	0.68	0.46	6.85	0.67	1.13
	F	0.77	0.59	7.57	0.62	0.73
	M + F	0.75	0.56	6.55	0.68	0.91

*r represents correlation coefficient; r^2, Coefficients of determination
#Y is the sum of permanent canine, first and second premolars of one quadrant, while X is the sum of four mandibular incisors, in millimetres.

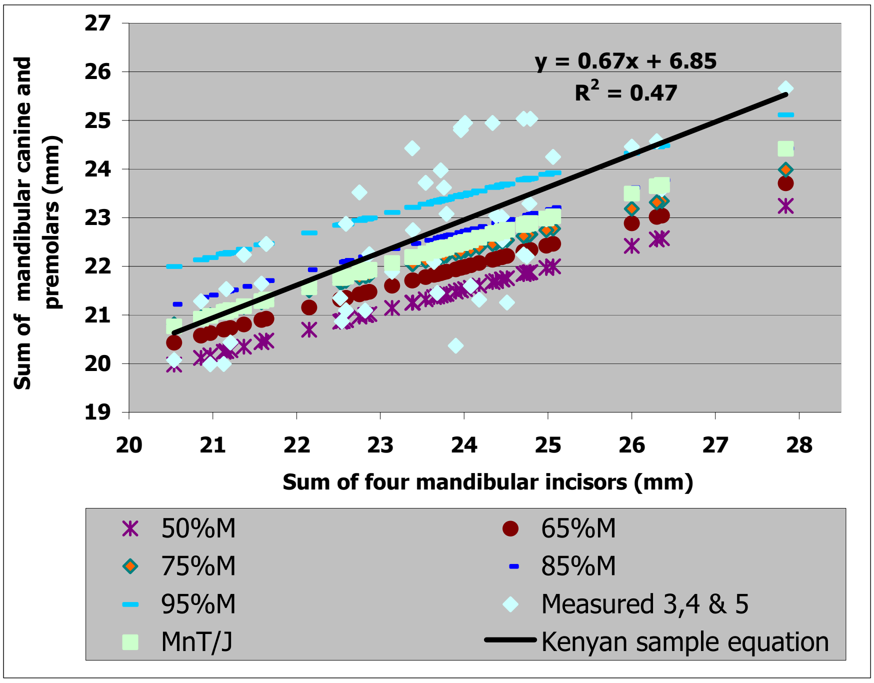

Figure 5.1; Graphic comparison of predicted values of unerupted mandibular canines, first and second premolars from Moyers (1988) at 50% - 95% probability levels, Tanaka and Johnston equations and proposed Kenyan prediction equation for the male group.

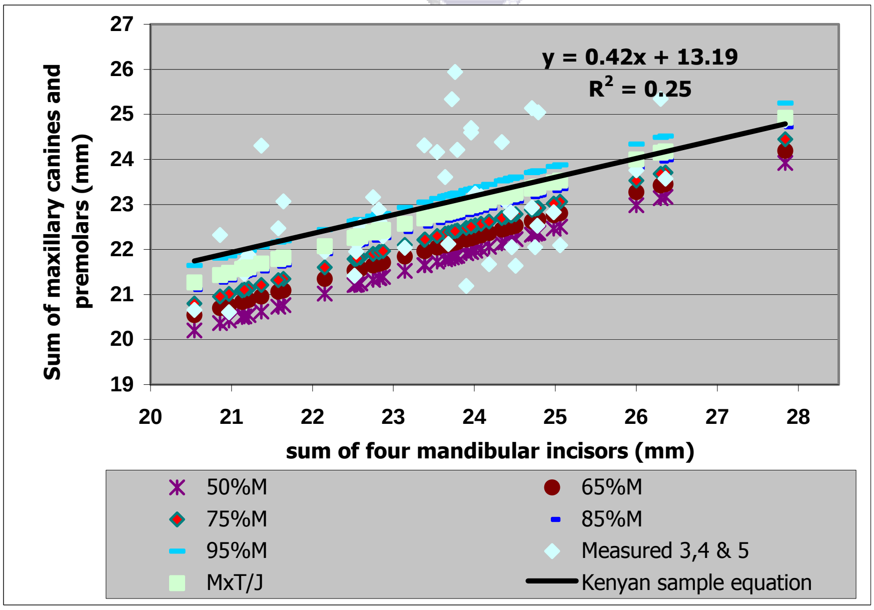

Figure 5.2; Graphic comparison of predicted values of unerupted maxillary canines and the two premolars from Moyers (1988) at 50% - 95% probability levels, Tanaka and Johnston equations and proposed Kenyan prediction equation for the male group.

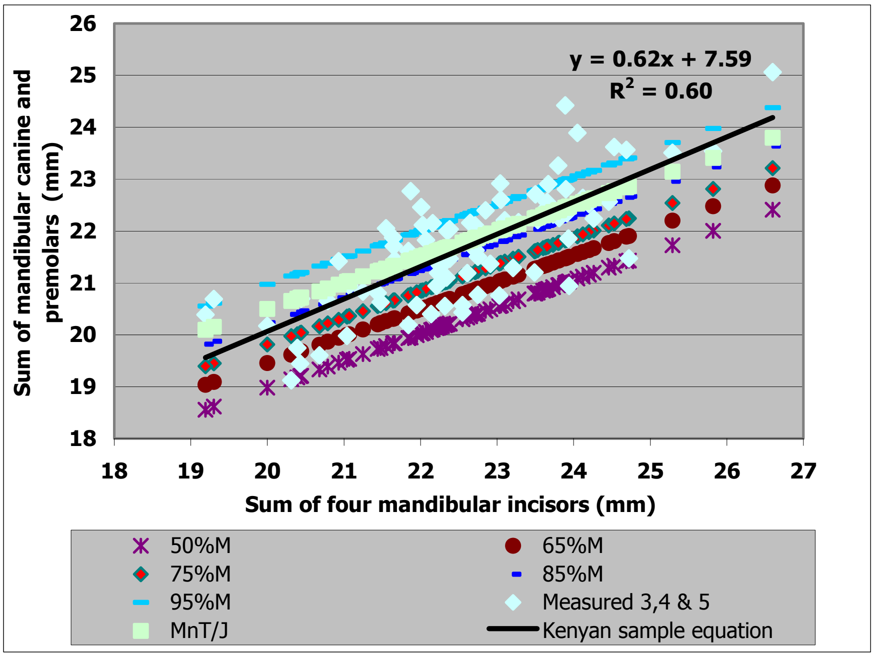

Figure 5.3; Graphic comparison of predicted values of unerupted mandibular canines, first and second premolars from Moyers (1988) at 50% - 95% probability level, Tanaka and Johnston equations and proposed Kenyan prediction equation for the female group.

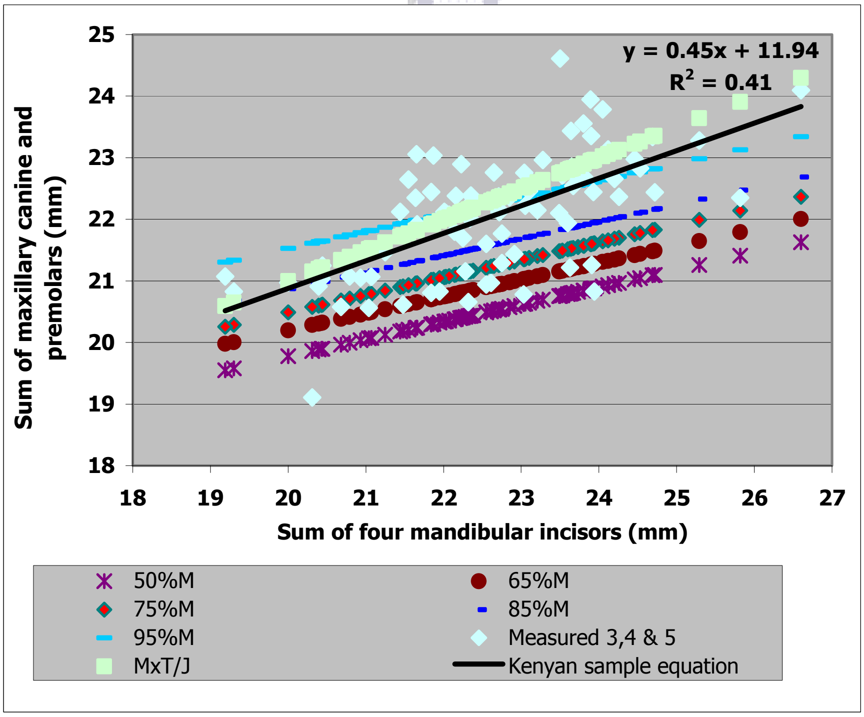

Figure 5.4; Graphic comparison of predicted values of unerupted maxillary canines, first and second premolars from Moyers (1988) at 50% - 95% probability level, Tanaka and Johnston equations and proposed Kenyan prediction equation for the female group.

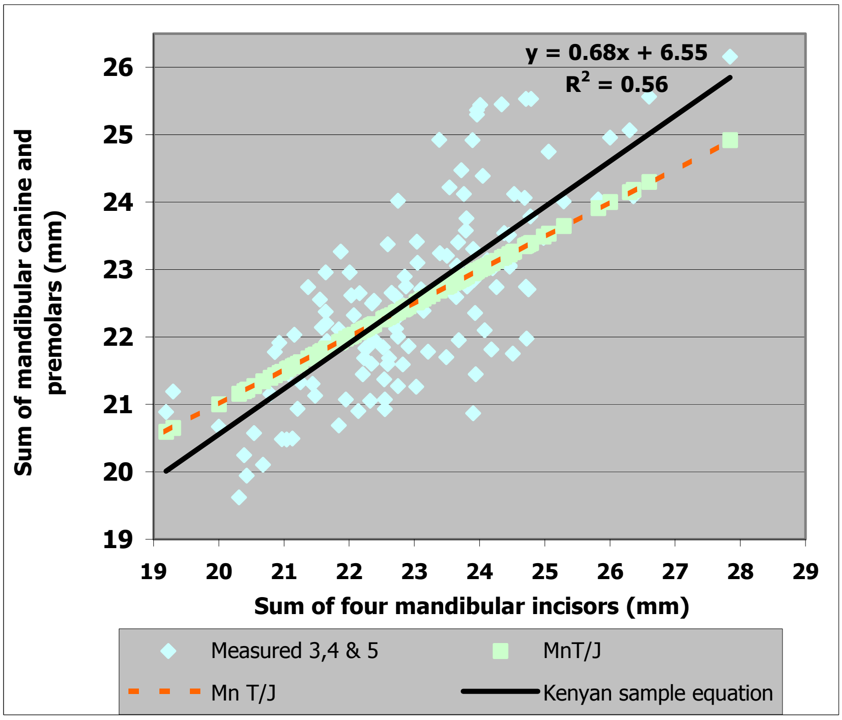

Figure 5.5; Sum of actual measurements of mandibular canines, first and second premolars compared to predicted values from Tanaka and Johnston (1974) for combined male and female groups.

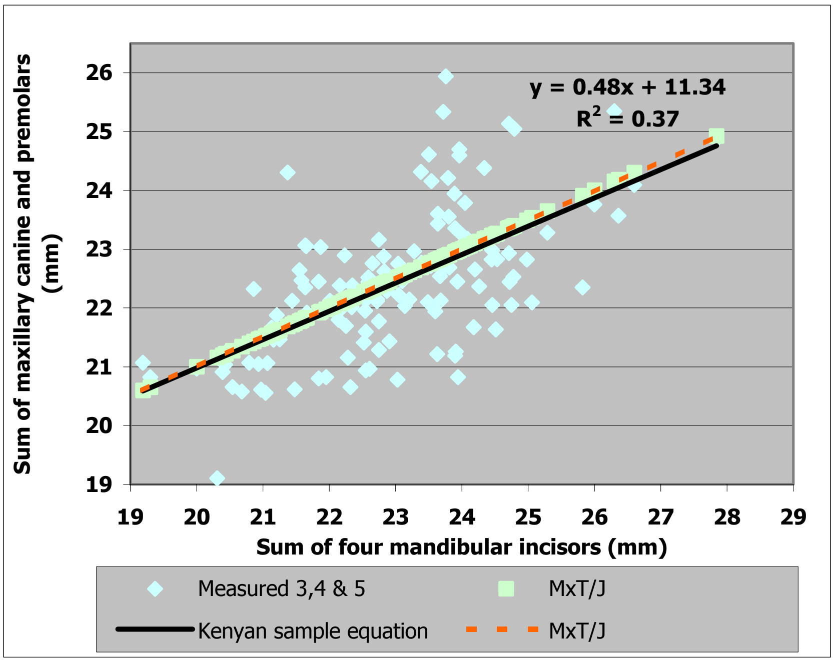

Figure 5.6; Sum of actual measurements of maxillary canines, first and second premolars compared to predicted values from Tanaka and Johnston (1974) for combined male and female groups

CHAPTER VI

DISCUSSION

6 DISCUSSION

6.1 Introduction

Measurement reliability is one of the most important aspects of odontometric studies and it refers to the ability to obtain the same measurement consistently over sequential measures (Oakley and Brunette, 2002). In an attempt to improve the reliability of the measurements undertaken in this present study the following procedures were employed:

- Use of high quality dental casts made from dental stone (Phillips, 1984; Zilberman et al., 2003).
- Use of callipers with digital display *(Mitutoyo™, Japan)* that could greatly help to reduce eye fatigue and the possibility of reading error (Zilberman et al., 2003).
- Assessing intraexaminer variability using Dahlberg's formula (Dahlberg, 1940). Method errors showed that differences between duplicate measurements ranged from 0.023 millimetres to 0.140 millimetres with averages of 0.080 millimetres and 0.044 millimetres in the mandibular and maxillary arches respectively (Table 5.2). These values compare favourably with those reported by other investigators (Seipel, 1946; Moorrees et al., 1957; Keene, 1979; Buschang et al, 1988) and were acceptable for the study of tooth sizes (Yuen et al, 1997). Buschang and co-workers (Buschang et al., 1988) obtained method error values that ranged from 0.06 millimetres to 0.14 millimetres. Using the same method, Yuen and his associates (Yuen et al., 1996) found method error, which ranged between 0.04 millimetres to 0.11 millimetres with a mean of 0.07 millimetres for permanent teeth, which were considered acceptable.

Therefore, any differences in the mesio-distal tooth widths, if observed, would result from the tooth size variability in the present sample and the prediction methods examined.

6.2 Representativeness of the sample

Since patients are usually referred to Kenyatta National Hospital from all over the country, and with the stratified random sampling (Bowling, 2003) that was employed, it was thought that this present sample would represent the Kenyan population. Population differences are influenced by historical, demographic and evolutionary (for example, gene flow) factors (Bishara et al., 1986). Although the homogeneity (exact genetic background) of the Kenyan population has not particularly been established in the present study, it was the investigator's conviction that the sample was appropriately selected to represent the "black" population. The degree of admixture in the Kenyan population, if any, is currently unknown. Furthermore, how genes translate their codes into crown sizes is not yet fully understood (Garn, 1977; Harzer, 1987).

Applicability of Moyers (1988) and Tanaka and Johnston (1974) predictions that have been conducted in Black American samples could give misleading results, since it has been reported that the black American population is a mixture of both black and white genes (Bailit, 1975; Macko et al., 1979) and that there is limited value in using standards of either parent population (Bailit, 1975; Garn, 1977). Studies have demonstrated the mesio-distal tooth dimensions are, to the largest extent, gene-determined (Lundstrom, 1964; Garn et al., 1965; Garn, 1977; Harzer, 1987). Environmental variables, such as nutrition, disease and climate, affect the dentition during the prenatal period (Garn et al, 1979) but seem to have little influence on normal dental variation (Bailit, 1975; Bishara et al., 1989). In the present study, the "black" population has been loosely defined by more of a "social" consideration (historical and demographic factors) rather than a biological one, as described by Macko and co-authors (Macko et al., 1979).

The study sample selection could not exclude patients with the crowded arches as the study was conducted on orthodontic patients. Patients with malocclusions have been shown to have no differences in tooth size compared with those with no malocclusions (Howe et al., 1983); therefore, the use of the patients presenting for orthodontic treatment in the Kenyan sample was considered acceptable.

The goal of any clinical study is to be able have sufficient numbers of subjects so that clinically meaningful differences are also statistically significant (Phillips, 2002). The determination of sample size (Altman, 1982) was appropriately done to provide sufficient power to determine any differences at confidence interval of at least 95 per cent (Phillips, 2002; Oakley and Brunette, 2002; Petrie et al., 2002c, Pallant, 2003). This means that at the 95 per cent level of confidence the true size of the combined mesio-distal widths of permanent canines and two premolars in one quadrant in an individual is within a range of plus and minus two times the error of the estimate from the expected value.

6.3 Mesio-distal tooth widths

The mean mesio-distal tooth widths are presented in the study so as to provide some odontometric data on the Kenyan population, which were previously not available, and these are compared with those of different ethnic groups.

6.3.1 Bilateral symmetry

Absolute mean differences between the left and right mesio-distal widths of any individual tooth ranged from 0 to 0.04 millimetres. Only mandibular lateral incisors, maxillary canines and first premolars showed statistically significant bilateral differences of 0.04 millimetres ($p<0.05$). But, when Bonferroni correction was applied ($p<0.005$), no statistically significant bilateral differences between them were observed (Table 5.4). The present study and previous odontometric studies (Moorrees et al., 1957; Moorrees and Reed, 1964; Garn et al., 1966; Moyers et al., 1976; Bishara et al., 1986) have shown that neither the left nor right side is systematically larger in the mesio-distal size of the permanent teeth. Additionally, these absolute mean differences were very small in magnitude and not clinically significant (Bishara et al., 1986). There were also no statistically significant differences between left and right (mandible, $p=0.274$ and maxilla, $p=0.657$) of combined mesio-distal widths of permanent canines and premolars (Wangpichit et al., 2001) as shown in Table 5.5.

Studies of tooth sizes in Caucasian Americans have generally found small and clinically insignificant bilateral tooth differences with no apparent pattern of left-right dominance (Ballard, 1944; Moorrees and Reed, 1964; Moyers et al., 1976; Staley and Hoag, 1978). These observations have also been made in several other ethnic groups (Richardson and Malhotra, 1975; Staley and Hoag, 1978; Macko et al., 1979; Keene, 1979; Bishara et al., 1989; Hattab et al., 1996; Otuyemi and Noar, 1996). These findings indicate that the right or the left side measurements, for both sexes, could be taken to represent the mesio-distal tooth widths for this sample. This agreed with the usual practice that teeth on one side of the jaw, or averages of the two, could be used for analysing the mesio-distal widths of teeth (Seipel, 1946, Moorrees and Reed, 1964; Bishara and Jakobsen, 1998). In this study, the averaged values of right and left sides of each jaw were used in the statistical analyses (Moorrees and Reed, 1964; Jaroontham and Godfrey, 2000).

6.3.2 Sex differences

It should be noted that, although generally desirable, it is not always necessary to have an equal number of subjects (Petrie et al., 2002b). Since the number subjects in the female group was more than the male group independent sample t tests (and Lavene's test) were performed to compare the mesio-distal tooth widths of the male and female subjects (Pallant, 2003).

The results of independent t-test presented in Table 5.6 showed that the mean mesio-distal tooth widths of male subjects were found to be consistently larger than females in both mandibular and maxillary dental arches, and the differences were statistically significant (*p*<0.05). The most pronounced statistically significant differences were shown by both maxillary and mandibular canines and maxillary central incisors, while smallest differences occurred in both incisors of mandibular arch, and in the two premolars of the maxillary arch. However, with Bonferroni correction (*p*<0.005) the mean mesio-distal widths of maxillary teeth failed to show any statistically significant sex differences except those of maxillary first premolars (*p*=0.02) and lateral incisors (*p*=0.012). The most pronounced differences were shown by both maxillary (0.5±0.08 mm) and mandibular (0.4±0.08 mm) canines, and maxillary central incisors (0.4±0.10 mm), while smallest differences by maxillary first premolars (0.19±0.08 mm).

A majority of odontometric studies have also found average mesio-distal widths of individual male teeth to be larger than those of female teeth of permanent dentition in any ethnic group (Moorrees et al., 1957; Garn et al., 1964; Arya et al., 1974; Staley and Hoag, 1978; Keene, 1979; Richardson and Malhotra, 1975; Doris et al., 1981; Lysell and Myrberg, 1982; Axelsson and Kirveskari, 1983; Bishara et al., 1986; Buschang et al., 1988; Van der Merwe et al, 1991; Hattab et al., 1996; Yuen et al., 1997; Bishara and Jakobsen, 1998). Macko et al. (1979) found that the mean difference in tooth size between males and females ranged from zero millimetres for the first premolars to 0.42 millimetres for maxillary central incisors. In their study of mesio-distal tooth widths in a Black American sample the tooth types that demonstrated male-female differences at *p*<0.01 were the maxillary central incisor and canine, and the mandibular canine and second premolar. In contrast, the mesio-distal measurements for the Iraqi males were generally larger than for the females, but the difference only reached the level of significance (*p*<0.05) in the canines (Ghose and Baghdady, 1979). Other studies have found no significant differences in mesio-distal widths of both maxillary and mandibular incisors (Garn et al, 1964; Lysell and Myrberg, 1982; Bishara et al, 1986, 1989; Yuen et al., 1997; Bishara and Jakobsen, 1998). Surprisingly, the maxillary incisors showed pronounced sex difference in mesio-distal tooth sizes in the present study.

The mean sum of mesio-distal widths of permanent canine and premolars in one quadrant of the male subjects was significantly larger than that of the females (mandible, p=0.274; maxilla, p=0.657) (Table 5.5), as observed in several other studies (Moorrees and Chadha, 1962; Staley and Hoag, 1978; de Paula et al., 1995; Yuen et al., 1998; Jaroontham and Godfrey, 2000; Diagne et al., 2003).

6.3.3 Population differences

Most odontometric studies have found mesio-distal tooth widths to be generally larger in black populations than in Caucasian ones (Richardson and Malhotra, 1975; Macko et al., 1979; Keene, 1979; Frankel and Benz, 1986; Merz et al., 1991; Otuyemi and Noar, 1996). Comparisons of mean mesio-distal tooth widths in the present study and in other black population groups (Richardson and Malhotra, 1975; Macko et al., 1979; Kieser and Groeneveld, 1988) to those in Caucasian populations (Moorrees et al., 1957; Moyers et al, 1976) have confirmed that the black subjects have generally larger teeth for all tooth types for both sexes (Table 6.1). When mesio-distal widths of tooth groups were compared, the Black Americans tend to have smaller values compared to other Black groups including this Kenyan sample (Frankel and Benz, 1986). However the present sample tend to have smaller combined mesio-distal tooth widths in both sexes than the black South African (Schirmer and Wiltshire, 1997); while these tooth widths almost parallel the Senegalese ones (Diagne et al., 2003) (Table 6.2). Numerous investigators have found differences in mesio-distal tooth sizes and subsequently suggested a number of diagnostic standards in the mixed dentition analysis for various ethnic groups; therefore, the use of any other standards of tooth sizes may not be accurate for the black Kenyan orthodontic patients in the mixed dentition analysis (Ballard and Wylie, 1947; Carey, 1949; Moyers, 1973; Tanaka and Johnston, 1974; Ferguson et al., 1978; Staley et al., 1984; Frankel and Benz, 1986; Motokawa et al., 1987; Bishara et al., 1989; Van der Merwe et al., 1991; Al-Khadra, 1993; Schirmer and Wiltshire, 1997; Yuen et al., 1998; Lee-Chan et al., 1998; Jaroontham and Godfrey, 2000; Nourallah et al., 2002; Diagne et al., 2003; Legovic et al., 2003). These mesio-distal width averages of teeth in the present study may be useful and serve as a diagnostic guide in the Kenyan situation. Tooth size prediction for an individual, though more complex, would be relatively more accurate and reliable in the formulation of orthodontic treatment plan and carrying out the treatment.

Table 6.1; Comparisons of mean mesio-distal tooth widths in millimetres with various other studies for male and female subjects

#See the list of abbreviations for definitions on page XIV.

Tooth#	North American Caucasians (Moorees et al., 1957)	North American Caucasians (Moyers et al., 1976)	African Americans (Richardson and Malhotra, 1975)	African Americans (Macko et al.. 1979)	Black South Africans (Kieser and Groeneveld, 1988)	Kenyans (Present study)
			Male			
Mx Pm2	6.82	6.67	7.25	7.04	7.39	7.22
Mx Pm1	7.01	6.76	7.66	7.50	7.68	7.58
Mx C	7.95	7.99	8.19	8.08	8.12	8.18
Mx Li	6.64	6.88	7.26	7.25	7.56	7.30
Mx Ci	8.78	8.91	9.12	9.25	9.28	9.16
Mn Pm2	7.29	7.22	7.85	7.69	7.90	7.70
Mn Pm1	7.07	6.89	7.76	7.52	7.86	7.68
Mn C	6.96	6.96	7.37	7.18	7.57	7.24
Mn Li	5.95	6.04	6.13	6.21	6.43	6.13
Mn Ci	5.42	5.54	5.53	5.55	5.61	5.62
			Female			
Mx Pm2	6.62	6.50	6.94	6.92	7.10	6.99
Mx Pm1	6.85	6.60	7.37	7.50	7.55	7.39
Mx C	7.53	7.49	7.74	7.78	7.90	7.89
Mx Li	6.47	6.78	7.08	7.02	6.94	7.03
Mx Ci	8.40	8.67	7.72	8.83	8.72	8.76
Mn Pm2	7.02	7.07	7.61	7.54	7.77	7.49
Mn Pm1	6.87	6.78	7.41	7.52	7.62	7.41
Mn C	6.47	6.58	6.86	6.80	7.27	6.83
Mn Li	5.78	5.92	5.99	6.06	6.11	5.91
Mn Ci	5.25	5.46	5.38	5.40	5.42	5.41

Table 6.2; Comparisons of sum mesio-distal widths of groups of teeth between the present and other studies in black populations (Mean±SD in millimetres).

Groups of teeth	Sex	African Americans (Frankel and Benz, 1986)	Black South Africans (Schirmer and Wiltshire, 1997)	Senegalese (Diagne et al., 2003)	Kenyans (Present Study)
Mandibular ∑ 4 incisors	M	23.06±1.59	23.92±1.90	23.71±1.25	23.50±1.55
	F	22.94±1.28	23.66±1.59	22.86±1.12	22.65±1.40
Mandibular ∑ 3, 4 & 5	M	22.57±1.45	23.22±1.11	22.70±1.01	22.62±1.62
	F	21.58±0.94	22.28±1.26	21.87±0.77	21.72±1.14
Maxillary ∑ 3, 4 & 5	M	22.53±1.30	23.45±1.37	22.60±1.22	22.98±1.30
	F	21.78±0.83	22.20±1.24	21.64±0.99	22.06±0.98

6.4 Comparisons of prediction methods with actual values

Statistics are used to make rational decisions under conditions of uncertainty (Petrie et al., 2002a-d). Many a times, it has been stated in the literature that clinical observations must be backed up by statistical evidence (Oakley and Brunette, 2002; Bowling, 2003). Conversely, clinical significance of statistically significant observations need not be ignored (Johnston, 2002; Oakley and Brunette, 2002; Bowling, 2003). A confidence interval for the effect of interest such as the average difference of mesio-distal width measurements enables the researcher to determine whether or not there is sufficient evidence to conclude that the difference is of clinical significance (Johnston, 2002; Phillips, 2002; Oakley and Brunette, 2002; Petrie et al., 2002c; Pallant, 2003; Bowling, 2003). Thus, few parameters can be predicted with sufficient accuracy and precision to be useful to the orthodontist in the planning of treatment and actual treatment (Johnston, 2002). In the mixed dentition, such an uncertainty exists in the determination of mesio-distal widths of unerupted permanent teeth. Although regression analyses are used in the mixed dentition analysis they assume that independent variables are measured without error, a clear impossibility in social and behavioural science research (Johnston, 2002; Bowling, 2003; Pallant, 2003). However, the best a researcher or a clinician can do is to choose the most reliable independent variable possible. Seipel (1946) stated "the exactitude of the measurement depends on the safety of the chosen points, the precision of the measuring instrument, and on the way in which the investigator uses it". It may not be possible to attain very high precision in predictive methods based on tooth size measurements on dental casts, though reasonably reliable prediction can benefit a mixed dentition patient and the orthodontist by assisting in the development of a sound diagnosis (Staley et al., 1979). Moyers (1988) claimed that, from the mandibular incisors on cast alone, 95 per cent of the patients have combined mesio-distal widths of canine and premolars within one millimetre of the predicted value in his tables, which should be considered clinically acceptable.

Most studies, to date, have found the sum of the four mandibular incisors to be still one of best predictors in the linear regression equations for determining the combined mesio-distal widths of the unerupted permanent canines and premolars both in the mouth (Motokawa et al., 1987) and dental casts (Ballard and Wylie, 1947; Huckaba, 1964; Moyers, 1973, 1988; Van der Merwe et al., 1991). Since several clinical advantages of using the four permanent mandibular incisors in prediction equations and probability tables have previously been demonstrated (Ballard and Wylie, 1947; Carey, 1949; Tanaka and Johnston, 1973; Moyers, 1973; 1988) the present study also used four permanent mandibular incisors as the independent variable. Such advantages include the ease of measuring four permanent mandibular incisors both in the mouth (Seipel, 1946; Motokawa et al., 1987) and on the dental casts (Hunter and Priest, 1960; Moyers, 1973; 1988). Although moderate correlation values have also been found in other predictors (Van der Merwe et al., 1991; Nourallah et al., 2002; Legovic et al., 2003), their use in the regressions are limited because of local complicating factors. These include distal gingival coverage or late eruption, as in the use of a combination of two permanent mandibular first molars and the four permanent mandibular incisors; or morphological drawbacks as in when combination of maxillary four permanent incisors due to deformity of the maxillary lateral permanent incisors (Nourallah et al., 2002; Legovic et al., 2003).

If there are systematic differences in the dependent variable (sum of permanent canines and the two premolars in a quadrant) associated with the levels of the sum of the four mandibular incisors (predictor) these differences are attributed to the predictor (Phillips, 2002; Oakley and Brunette, 2002; Petrie et al., 2002c; Pallant, 2003). The goal of the present study is to examine the ability of the predictor to reproduce the values of the mesio-distal widths of permanent canines, first and second premolars in one quadrant. The mean differences (residuals) between the predicted and measured values can be used as the measure of error of the predictions. The squared value of residuals or the absolute mean differences provide a measure of how good the prediction is. When the predictions are close to the measured values, the squared errors or the absolute mean differences are small (Tables 5.8-5.11).

Permanent teeth may be either wrongly retained or extracted on the basis of an inaccurate tooth size prediction (White, 1978). Underestimation of the mesio-distal tooth widths would result in a more conservative clinical approach, while overestimation tends to exaggerate space requirements and result in unnecessary extractions. Theoretically, the 50 per cent probability level is used as the estimate in all regression equations since any error would be distributed equally in either direction (Moyers, 1988; Jaroontham and Godfrey, 2000; Wangpichit et al., 2001). Clinically, the value at the 75 per cent level is used as the estimate because more protection on the down side (crowding) is required than that of on the up side (spacing), (Moyers, 1988). Seventy-five percent level of probability means that 75 times out of 100 the unerupted canine and premolars will be at the predicted value or less (Moyers, 1988). Nevertheless, the choice of percentile levels to be used may vary among clinicians depending on the application and experience of the clinician (Moyers, 1988; Yuen et al., 1998; Wangpichit et al., 2001)

Moyers (1988) at 85 per cent and/or 95 per cent probability levels and Tanaka and Johnston (1974) could be used to estimate the combined mesio-distal widths of unerupted permanent canines and the two premolars in one quadrant, because their mean differences with measured values derived from the present sample were small and not statistically significant. All differences were not statistically significant with Bonferroni (p<0.003) correction (Tables 5.8-5.11). In the mandibular arch, Moyers (1988) prediction (at 85 per cent probability level) underestimated the combined mesio-distal widths of unerupted permanent canines and first and second premolars by 0.10±1.18 millimetres in the male subjects and 0.12±0.74 millimetres for the female group. While the Tanaka and Johnston (1974) prediction overestimated the actual values by 0.30±1.15 millimetres in the male subjects and, in the female subjects, Tanaka and Johnston (1974) underestimated the actual measured by 0.10±0.74 millimetres in the mandibular arch. In the maxilla, Moyers (1988) prediction (at 95 per cent probability level) overestimated the measured values of the combined mesio-distal tooth widths for male (0.13±1.13 mm) and female (0.19±0.79 mm) subjects, but underestimated the actual values at 85 per cent probability level in the male (-0.4±1.13 mm) subjects. Tanaka and Johnston (1974) showed an overestimation in the male (0.23±1.13 mm) subjects, but underestimated actual combined mesio-distal widths in female (-0.26±0.78 mm) subjects when the maxillary arch was assessed. Schirmer and Wiltshire (1997) found highly significant differences ($p<0.001$) between the values of the black South Africans at all percentiles except in the maxilla for females at 75%, 85% and 95% confidence levels. Jaroontham and Godfrey (2000) did not find Moyers at 50% to be accurate for predicting the sum of canine and premolars for both sexes in a Thai population.

The sum of unerupted permanent canines and first and second premolars in each quadrant could probably be estimated from the Tanaka and Johnston (1974) in the Kenyan sample as illustrated in scattergrams (Figures 5.1-5.6). This could only be so for the sum of four mandibular incisors in the range between 22.5 millimetres and 24 millimetres (Figure 5.1). While the slopes of predictions at 85 per cent Moyers (1988) probability level do not show any close relationship, but at 95 per cent does show some closeness for the full range of the mandibular incisors (Figure 5.2). Conversely, for the female subjects, Moyers (1988) at 85 per cent probability level shows a very close relationship (Figure 5.3), and Moyers (1988) at 95 per cent probability level at a slightly wider range (21.5-25 mm) of the sum of four mandibular incisors (Figure 5.4). Although these observations were made, Moyers (1988) prediction at 85 per cent or 95 per cent probability level may be too high for predictions of combined mesio-distal widths of permanent canines, first and second premolars for any population group. Moyers (1988) predictions at these confidence levels may be statistically acceptable but not clinically acceptable in this present sample since they are too far above the clinically recommended 75 per cent probability level (Moyers, 1988). Moreover, it has been reported that at 75% confidence level and above, Moyers (1988) predictions tend to overestimate the actual dental measurements (Kaplan et al., 1977; Zilberman et al., 1977).

Jaroontham and Godfrey (2000), like in this present study, found predictions from Tanaka and Johnston (1974) to be close to the actual mesio-distal measurements of permanent canines and premolars of Thai subjects; sexes pooled, and of male and female separately. While other investigators have found the predicted values derived from Tanaka and Johnston (1974) to be significantly larger than the actual measurements of the unerupted permanent canines and the two premolars in a quadrant (Staley and Hoag, 1978; Al-Khadra, 1993; Wangpichit et al., 2001; Diagne et al., 2003). Underprediction has also been found with Tanaka and Johnston (1974) in some studies (Lee-Chan et al., 1998; Yuen et al., 1998). Kaplan et al. (1977) found that both Moyers (1988) and Tanaka and Johnston (1974) predictions generally tend to overestimate the size of unerupted permanent canine first and second premolars.

6.5 Regressions equations

The accuracy of the prediction is often expressed as the standard error of the estimate (mean) for the prediction equations (Johnston, 2002). In this study the standard error of estimates (SEE) are presented in Table 5.13 ranged from 0.73 millimetres to 1.14 millimetres for male, female and combined groups, and compared with other studies (Tanaka and Johnston, 1974; Ferguson et al., 1978; Frankel and Benz, 1986; Diagne et al., 2003) (Table 6.3). As Ballard and Wylie (1947) had advocated, the prediction method should not be adopted as a superscientific method of arriving mysteriously at the precise diameter of the unerupted canines and premolars. The errors involved in measurement and prediction equations should be recognized (Oakley and Brunette, 2002). The smaller the error of estimate (mean) the more accurate the prediction equation. The magnitude of a standard error of the mean is inversely proportional to the number of observations (that is, the larger sample size the smaller the SEE). Therefore, it may not be plausible to use this parameter in comparison of these Kenyan equations with those of other studies due to differences in the sample sizes (Table 6.2) (Tanaka and Johnston, 1974; Ferguson et al., 1978; Frankel and Benz, 1986; Diagne et al., 2003).

Pearson product moment correlation is independent of both scale of measurement and sample size (Rosner, 1990) and was, therefore used for comparisons of the prediction equations. Correlation coefficients ranged from 0.50 to 0.77 (Table 5.13) and were all statistically significant ($p<0.01$). A correlation coefficient that is equal to or greater than 0.6 is usually considered to be clinically significant (Johnston, 2002). The correlation coefficients (r) of the regression equations for the whole sample does not seem to differ significantly from the ones of the either sex for both the maxillary and mandibular teeth (Table 5.13). The correlation coefficients for the Kenyans between the sum of the four mandibular incisors and the combined sum of mesio-distal widths of unerupted permanent canines and the two premolars of each arch were found to be smaller than for the Senegalese (Diagne et al., 2003) for male subjects but larger in female subjects. These correlation coefficients are comparable, in combined sexes and the female subjects in the maxilla, to African American groups (Table 6.3). They are larger than those of African American groups in the mandible, but smaller in the maxilla of the male subjects (Table 6.3). Coefficients of determination (r^2) are indicators of predictive accuracy of the regression equations for y (the sum of mesio-distal widths of canine and premolars) based on values of x (the corresponding sum of mesio-distal widths of four mandibular incisors), that is, the proportion of the total variance of y, which is determined then value of x for each regression equation. The same pattern as in r-values is obtained with r^2 values. Although a regression equation must have an r^2-value of at least 0.5 to be clinical useful (Johnston, 2002), the r^2 tends to overestimate the true reliability (Oakley and Brunette, 2002).

Table 6.3; Comparisons between regression equations

					Regression Coefficient	**SEE**

Study	Sex	Arch	r	r²	A	B	(mm)
Ferguson et al. (1978)	M + F	Mn	0.71	0.50	9.94	0.53	-
		Mx	0.63	0.40	11.98	0.45	-
Frankel and Benz (1986)	M	Mn	0.66	0.51	5.97	0.72	0.91
		Mx	0.72	0.62	9.15	0.58	0.92
	F	Mn	0.66	0.37	10.34	0.49	0.71
		Mx	0.61	0.43	12.83	0.39	0.67
	M + F	Mn	0.70	0.42	8.30	0.64	0.95
		Mx	0.65	0.49	10.18	0.52	0.87
Diagne et al. (2003)	M	Mn	0.73	0.54	5.45	0.72	0.82
		Mx	0.68	0.46	9.60	0.55	0.74
	F	Mn	0.63	0.40	8.74	0.56	0.76
		Mx	0.51	0.26	13.77	0.35	0.66
	M + F	Mn	0.73	0.54	5.67	0.70	0.81
		Mx	0.68	0.46	9.87	0.53	0.71
Tanaka and Johnston (1974)	M + F	Mn	0.65	0.42	9.18	0.54	0.85
		Mx	0.63	0.40	10.41	0.51	0.86
Present study	M	Mn	0.68	0.46	6.85	0.67	1.13
		Mx	0.50	0.25	13.19	0.42	1.14
	F	Mn	0.77	0.59	7.57	0.62	0.73
		Mx	0.64	0.41	11.94	0.45	0.76
	M + F	Mn	0.75	0.56	6.55	0.68	0.91
		Mx	0.61	0.37	11.33	0.48	0.95

6.6 Comparison of prediction methods

Some investigators have shown that the use of both sexes together is possible without impairment of the results in the calculation of correlations between the sizes of teeth (Moorrees and Reed, 1964; Kaplan et al., 1977; Ingerval and Lennartsson, 1978; Gardner, 1979;). However, it is quite clear from results of most odontometric studies that sex dimorphism does exist in mesio-distal widths of permanent teeth (Bishara et al., 1989; Diagne et al., 2003; Legovic et al., 2003). Sex dimorphism is also demonstrated in this present study.

Direct comparison between Tanaka and Johnston (1974) and Moyers (1988) prediction methods was not done. The comparison between them for the whole sample would have biased the results as Moyers (1988) prediction tables were categorized according to sex, while this was not provided for, in the study by Tanaka and Johnston (1974). It can be observed that there is a statistically significant sex difference in mesio-distal tooth widths of the sum of the groups of teeth (Table 5.7), which necessitated the division of the subjects according to sex when determining the optimal simple regression equations for the Kenyan sample. However, it was assumed that, by comparing both methods to the measured values of the sum of permanent canines, first and second premolars, relationships between the two methods could be closely examined and evaluated. Although from the literature (Tanaka and Johnston, 1974; Kaplan et al., 1977; Wangpichit et al., 2001) Tanaka and Johnston (1974) predictions tend to fall somewhere between 65 per cent and 75 per cent probability levels of Moyers (1973) predictions, these comparisons may not be accurately applied to those of Moyers (1988) tables with separate sexes. It was only Moyers (1988) at 85 per cent probability level that was coincident with Tanaka and Johnston (1974) prediction values in this Kenyan sample (Figure 5.3). Although all these findings indicate some differences between the actual measurements and the predicted mesio-distal widths of canines and premolars, their absolute differences did not exceed one millimetre

(Schirmer and Wiltshire, 1997). Thus, the difference between Tanaka and Johnston (1974) and Moyers at 85 per cent and/or 95 per cent probability levels may not be statistically significant (Moyers, 1988). One would have expected that the Moyers (1988) prediction between 65 % and 75% confidence level to be consistently coincident to the Tanaka and Johnston (1974) in this study.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. The findings of this study provide Kenyan odontometric data which were previously unavailable.

2. Moyers (1988) prediction tables are not suitable for estimating the combined mesio-distal widths of unerupted of the canines and two premolars in any one quadrant of the Kenyan black subjects.

3. The regression equations for the combined sexes are better than those for either sex.

4. Tanaka and Johnston (1974) seems to be suitable for clinical use in the mixed dentition analysis of the black Kenyan patient, since the Kenyan regression equations are not any better than the simplified Tanaka and Johnston (1974) analysis.

7.2 Recommendations

More research is needed on several key issues to establish firm scientific basis for future use of odontometric tools in Kenya, including ethnic homogeneity in mesio-distal measurements and generalizability of the present odontometric data.

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9 APPENDICES

Appendix I; Approval letter from Ethics and Research committee of Kenyatta National Hospital

KENYATTA NATIONAL HOSPITAL
Hospital Rd. along, Ngong Rd.
P.O. Box 20723, Nairobi.

Tel: 726300-9
Fax: 725272
Telegrams: "MEDSUP", Nairobi.
Email: **KNHplan@Ken.Healthnet.org**

Ref: KNH-ERC/01/1746

Date: 10 April 2003

Dr. Ngesa James Lwanga
Dept. of Orthodontics
University of the Western Cape

Dear Dr. Ngesa,

RESEARCH PROPOSAL "APPLICABILITY OF TOOTH SIZE PREDICTIONS IN THE MIXED DENTITION ANALYSIS IN A KENYAN SAMPLE" (P142/12/2002)

This is to inform you that the Kenyatta National Hospital Ethics and Research Committee has reviewed and **approved** the revised version of your above cited research proposal.

On behalf of the Committee, I wish you fruitful research and look forward to receiving a summary of the research findings upon completion of the study.

This information will form part of database that will be consulted in future when processing related research study so as to minimize chances of study duplication.

Yours sincerely,

PROF. A. N. GUANTAI
SECRETARY, KNH-ERC

Cc Prof. K.M. Bhatt, Chairperson, KNH-ERC
The Deputy Director (C/S), KNH
The Dean, Faculty of Medicine, UON
The Dean, Faculty of Dental Sciences, UON
The Chairman, Dept. of Orthodontics, UON
CMRO
Supervisors: Dr. E.T.L. Theunissen
Dr. A. Shaikh

Appendix II; Patient consent form used in this study

Please read and understand before filling in the consent form below.

A RESEARCH PROJECT OF THE UNIVERSITY OF THE WESTERN CAPE (Republic of South Africa)

By Dr JAMES L. NGESA

Tooth size predictions STUDY will involve taking alginate impressions of your child's dentition and study casts will be made from them. The individual teeth from the study casts are going to be measured and analysed in the study. No invasive procedures shall be performed and the measurements taken constitute part of the treatment planning procedures. The orthodontic treatment schedules will not be affected in any way. The participation is voluntary and you or your child can withdraw from the study at any time. The results of the study will be confidential and anonymous. The results of the study are to be presented by Dr JAMES L. NGESA to the UNIVERSITY OF THE WESTERN CAPE as part fulfilment of the award of master's degree and as publications in a reputable scientific journal.

CONSENT FORM

Please fill the form in ink.

I, (father, mother or guardian)………………………………….. herewith grant permission for my child, …………………………………………………to participate in the above-mentioned study. No invasive procedures shall be performed and the measurements taken constitute part of the treatment planning procedures.

I have been informed, in writing, of the procedures to be performed. I understand that the study is voluntary and that the results of the study will be anonymous.

Name: Witness:…………………………………………………

Signature: Signature:……………………………………………….

Date: Date:…………………………………………………….

Appendix III; Moyers Prediction tables (Moyers, 1988)

Probability Tables for Predicting the Sizes of Unerupted Cuspids and Bicuspids*

A, Mandibular Bicuspids and Cuspids

21/12 = (%)	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5
						MALES							
95	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	23.5	23.7	23.9	24.2
85	20.8	21.0	21.2	21.4	21.6	21.9	22.1	22.3	22.5	22.7	23.0	23.2	23.4
75	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.9	22.1	22.3	22.5	22.8	23.0
65	20.0	20.2	20.4	20.6	20.9	21.1	21.3	21.5	21.8	22.0	22.2	22.4	22.7
50	19.5	19.7	20.0	20.2	20.4	20.6	20.9	21.1	21.3	21.5	21.7	22.0	22.2
35	19.0	19.3	19.5	19.7	20.0	20.2	20.4	20.67	20.9	21.1	21.3	21.5	21.7
25	18.7	18.9	19.1	19.4	19.6	19.8	20.1	20.3	20.5	20.7	21.0	21.2	21.4
15	18.2	18.5	18.7	18.9	19.2	19.4	19.6	19.9	20.1	20.3	20.5	20.7	20.9
5	17.5	17.7	18.0	18.2	18.5	18.7	18.9	19.2	19.4	19.6	19.8	20.0	20.2
						FEMALES							
95	20.8	21.0	21.2	21.5	21.7	22.0	22.2	22.5	22.7	23.0	23.3	23.6	23.9
85	20.0	20.3	20.5	20.7	21.0	21.2	21.5	21.8	22.0	22.3	22.6	22.8	23.1
75	19.6	19.8	20.1	20.3	20.6	20.8	21.1	21.3	21.6	2.9	22.1	22.4	22.7
65	19.2	19.5	19.7	20.0	20.2	20.5	20.7	21.0	21.3	21.5	21.8	22.1	22.3
50	18.7	19.0	19.2	19.5	19.8	20.0	20.3	20.5	20.8	21.1	21.3	21.6	21.8
35	18.2	18.5	18.8	19.0	19.3	19.6	19.8	20.1	20.3	20.6	20.9	21.1	21.4
25	17.9	18.1	18.4	18.7	19.0	19.2	19.5	19.7	20.0	20.3	20.5	20.8	21.0
15	17.4	17.7	18.0	18.3	18.5	18.8	19.1	19.3	19.6	19.8	20.1	20.3	20.6
5	16.7	17.0	17.2	17.5	17.8	18.1	18.3	18.6	128.9	19.1	19.3	19.6	19.8

B, Maxillary Bicuspids and Cuspids

21/12 = (%)	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5
						MALES							
95	21.2	21.4	21.6	21.9	22.1	22.3	22.6	22.8	23.1	23.4	23.6	23.9	24.1
85	20.6	20.9	21.1	21.3	21.6	21.8	22.1	22.3	22.6	22.8	23.1	23.3	23.6
75	20.3	20.5	20.8	21.0	21.3	21.5	21.8	22.0	22.3	22.5	22.8	23.0	23.3
65	20.0	20.3	20.5	20.8	21.0	21.3	21.5	21.8	22.0	22.3	22.5	22.8	23.0
50	19.7	19.9	20.2	20.4	20.7	20.9	21.2	21.5	21.7	22.0	22.2	22.5	22.7
35	19.3	19.6	19.9	20.1	20.4	20.6	20.9	21.1	21.4	21.6	21.9	22.1	22.4
25	19.1	19.3	19.6	19.9	20.1	20.4	20.6	20.9	21.1	21.4	21.6	21.9	22.1
15	18.8	19.0	19.3	19.6	19.8	20.1	20.3	20.6	20.8	21.1	21.3	21.6	21.8
5	18.2	18.5	18.8	19.0	19.3	19.6	19.8	20.1	20.3	20.6	20.8	21.0	21.3
						FEMALES							
95	21.4	21.6	21.7	21.8	21.9	22.0	22.2	22.3	22.5	22.6	22.8	22.9	23.1
85	20.8	20.9	21.0	21.1	21.3	21.4	21.5	21.7	21.8	22.0	22.1	22.3	22.4
75	20.4	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.5	21.6	21.8	21.9	22.1
65	20.1	20.2	20.3	20.5	20.6	20.7	20.9	21.0	21.2	21.3	21.4	21.6	21.7
50	19.6	19.8	19.9	230.1	20.2	20.3	20.5	20.6	20.8	20.9	21.0	21.2	21.3
35	19.2	19.4	19.5	19.7	19.8	19.9	20.1	20.2	20.4	20.5	20.6	20.8	20.9
25	18.9	19.1	19.2	19.4	19.5	19.6	19.8	19.9	20.1	20.2	20.3	20.5	20.6
15	18.5	18.7	18.8	19.0	19.1	19.3	19.4	19.6	19.7	19.8	20.0	20.1	20.2
5	17.8	18.0	18.2	18.3	18.5	18.6	18.8	18.9	19.1	19.2	19.3	19.4	19.5

* Measure and obtain the mesial distal widths of the four permanent mandibular incisors and find that value in the horizontal row of the appropriate male or female table. Reading downward in the appropriate vertical column obtain the values for expected width of the cuspids and premolars corresponding to the level of probability you wish to choose. Ordinarily I use the 75% of probability rather than the mean of 50% since although the values distribute normally toward crowding and spacing, crowding is a much more serious clinical problem and the 75% predictive values thus protects the clinician on the safe side. Note that the mandibular incisors are used for the prediction of both the mandibular and maxillary cuspid and bicuspid widths.

Appendix IVa; Maxillary teeth measurement chart

Serial No.	Sex/Age (Month)		Right (mm)					Left (mm)				
			Pm2	Pm1	C	Li	Ci	Ci	Li	C	Pm1	Pm2

Appendix IVb; Mandibular teeth measurement chart.

Serial No.	Sex/Age (Month)		Right (mm)					Left (mm)				
			Pm2	Pm1	C	Li	Ci	Ci	Li	C	Pm1	Pm2

Appendix V; Tanaka and Johnston (1974) regression equations

Maxillary canine and premolars (3, 4 &5) in one quadrant=

(Sum of four mandibular incisors) /2 +11.00 mm

Mandibular canine and premolars (3, 4 &5) in one quadrant =

(Sum of four mandibular incisors)/2 +10.5 mm