COMPARISON OF MEASURED AND PREDICTED MESIODISTAL TOOTH-WIDTHS OF 13-17 YEAR OLD KENYANS

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR MASTER OF DENTAL SURGERY DEGREE IN PAEDIATRIC DENTISTRY AT THE UNIVERSITY OF NAIROBI.

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DECLARATION

I, Nduguyu Kerre, declare that this thesis is my original work and has not been presented for the award of a degree in any other university.

Signed.. Date...

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LIST OF ABBREVIATIONS

mm	- millimetre
Σ 3,4,5	- sum of mesiodistal tooth-widths of permanent canines, first and second premolars in each quadrant
Σ 31, 32, 41, 42	- sum of the four permanent mandibular incisors
Σ 36, 32, 31, 41, 42, 46	- sum of the four permanent mandibular incisors and first permanent molars
n	- sample size
p value	- ≤ 0.05
r	- correlation coefficient
r^2	- coefficient of determination
SD	- standard deviation
CV	- coefficient of variation

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SUMMARY

Background: Odontometric measurements are important in the determination of the space discrepancies in the dental arches. In clinical orthodontics, odontometric measurements are done to determine the arch perimeter and total tooth mass. In permanent dentition the odontometric measurements are straightforward. However, in the mixed dentition analysis, it is a great challenge to accurately determine the mesiodistal tooth-widths of unerupted permanent canines and premolars. Various methods have been proposed and used in different ethnic groups. They fall into three main categories; radiographic method, use of regression/prediction equations and a combination of radiographic method and regression equations. The most widely used prediction equations are the Tanaka and Johnston equation and the Moyers prediction tables. However, they have their shortcomings. This has necessitated the proposal of different prediction equations for use in various ethnic groups.

Objectives: To measure mesiodistal tooth-widths of permanent teeth in both the upper and lower dental arches from first molar to first molar, to estimate the mesiodistal tooth-widths of permanent canines and premolars using two prediction equations and to compare the measured values with values obtained using the two prediction equations.

Materials and methods: A descriptive cross-sectional study was carried out on 13-17 year old Kenyans in two secondary schools. Maxillary and mandibular arch impressions were made using irreversible hydrocolloid impression material and the impressions were then poured with type III dental stone. An electronic digital vernier calliper was used to measure the mesiodistal tooth-widths from the first molar to the antimeric first molar for both arches. Measurements were entered on a data collection form and later transferred to Microsoft Excel software. Statistical Package for Social Sciences (SPSS) version 14.0 for Windows was used for data analysis. Paired t-tests, independent t-tests and Pearson product moment correlation tests were used to analyse the data. Data were presented in the form of tables (Table 3.1 to 3.18) and graphs (Figures 3.1 to 3.5). The Tanaka and Johnston and Melgaço et al prediction equations were used to estimate the mesiodistal tooth-widths of the permanent canines and premolars and these values were compared with the measured values.

Results: Sixty eight subjects (28 males and 40 females) of mean age 14.89 ± 1.23 years (males) and 14.65 ± 1.21 years (females) were included in this study. Intra-class coefficient was 0.99 and it was used to assess the accuracy of measurements.

The male subjects had larger mean mesiodistal tooth-widths than female subjects. Statistically significant differences in mean mesiodistal tooth-widths were found in the mandibular and maxillary canines, first permanent molars and the maxillary lateral incisors. Except for the mandibular second premolar and the maxillary first permanent molar, the male sample showed no statistically significant differences between antimeric teeth. There were statistically significant differences between antimeric mandibular first and second premolars and the maxillary first permanent molar for the female sample. There were no statistically significant differences in the antimeric sum of mesiodistal tooth-widths of the permanent canine and premolars for both the mandibular and maxillary arches in males. However, in females both the mandibular and maxillary arches had statistically significant differences. Inclusion of the two first permanent mandibular molars to the four permanent mandibular incisors as predictor teeth gave higher correlation coefficients than the use of only four permanent mandibular incisors. The Tanaka and Johnston equation was useful as a prediction equation for the female maxillary arch and in the combined sample. The

Melgaço et al equation could be used as a prediction equation in the mandibular arch for males, females and the combined sample. There were no statistically significant differences in the sum of mesiodistal tooth-widths of the mandibular permanent canine and premolars between the actual and predicted values obtained using both the Tanaka and Johnston and Melgaço et al equations. There were no statistically significant differences in the calculated/predicted value of the sum of mesiodistal tooth-widths of the mandibular permanent canine and premolars obtained using the Tanaka and Johnston and Melgaço et al equations. However, the Melgaço et al equation had a correlation coefficient of 0.693 and the Tanaka and Johnston equation correlation coefficient was 0.465 for the sum of mesiodistal tooth-widths of the mandibular permanent canine and premolars and the predictor teeth.

Conclusion: Males had larger mean mesiodistal tooth-widths than females. The Melgaço et al equation predicted better the sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars than the Tanaka and Johnston equation but had lower correlation coefficients compared to the original sample from which it was derived. However, the Melgaço et al equation overestimated the mesiodistal tooth-widths for the female and combined samples and under-estimated for the male sample but the differences were not clinically significant.

Recommendation: Male and female mesiodistal tooth-widths should be calculated/estimated separately. The prediction equations formulated from this study should be used in predicting the sum of mesiodistal tooth-widths of mandibular permanent canines and premolars in Kenyan populations.

CHAPTER ONE

1.0 INTRODUCTION

Odontometric measurements are important in the determination of space discrepancies in the dental arches. In clinical orthodontics, odontometric measurements are done to determine the arch perimeter and total tooth mass. In permanent dentition the odontometric measurements are straightforward. However, in the mixed dentition analysis, it is a great challenge to accurately determine the mesiodistal tooth-widths of unerupted canines and premolars. This is because both deciduous and permanent teeth exist in the mouth at the same time. Mixed dentition analysis involves measurement of available space in the dental arch and space required in the arch to accommodate the erupting permanent teeth during the mixed dentition period. The space required represents the total tooth mass which is regarded as all permanent teeth mesial to the first permanent molar.

Several methods to analyze space discrepancy in the mixed dentition period have been described[1-14]. These analyses help to estimate the space discrepancy likely to occur when permanent teeth erupt. The various treatment modalities that can be done once the mixed dentition analysis has been performed include: serial extractions, guided eruption, proximal stripping or periodic observation of the patient[4]. There are three main prediction methods[4] which broadly are:

- Direct measurement of unerupted teeth from radiographs[8, 9, 10].
- Direct measurement of teeth from study models and use of prediction equations[1-7].

- Combination of the above two methods; use of prediction tables/equations combined with measurement of unerupted teeth on radiographs as described by Hixon and Oldfather[8].

The radiographic method involves direct measurement of teeth from periapical films[9] or cephalograms[10]. However, its use is challenging because the process is time consuming, specialized equipment is required, trained and skilled personnel are required to take the radiographs, the radiographs can either be over or under magnified requiring magnification correction[3,6] and rotation of a tooth in its crypt making its measurement difficult[6]. These challenges therefore limit the use of radiographs in estimating the mesiodistal tooth-widths of permanent canines and premolars[6].

Use of prediction equations is the most commonly used method[3,4,5] It is based on measurement of a group of erupted teeth from study models. This measurement is then used to predict the combined mesiodistal tooth-widths of a group of teeth in a quadrant using correlation and statistical methods[11,12]. They are quick, simple to use and require no radiographs[3]. Of the various prediction equations, Tanaka and Johnston[1] and Moyers[2] prediction tables are the most widely used[11,12]. They are however based on studies done on Caucasian children. Various studies have demonstrated the non-applicability of the Tanaka and Johnston[1] equation and the Moyers[2] prediction tables in different ethnic and racial groups[5]. Due to the differences observed, these two prediction equations have been modified to be applicable to the ethnic or racial group in which a study is done[5]. The modification of the Tanaka and Johnston[1] equation has been necessitated by differences in mesiodistal tooth-widths observed between different ethnic and racial groups[6] and also between gender[3,5].

On reviewing the literature, only one previous Kenyan study on this subject was found[6]. This study tested the applicability of both the Tanaka and Johnston[1] equation and the Moyers[2] prediction tables in a Kenyan sample[6]. The study found that the Moyers[2] prediction tables could not be applied accurately but the Tanaka and Johnston[1] equation could be applied accurately without modification[6]. A study on a Ugandan population[12] also tested the applicability of the Tanaka and Johnston[1] equation and Moyers[2] prediction tables. The study found that the Tanaka and Johnston[1] equation overestimated the mesiodistal tooth widths while the Moyers[2] tables could be used at different percentile levels for males and females. Diagne et al[13] in their study on a Senegalese population found that the Moyers[2] prediction tables and Tanaka and Johnston[1] equation could not be applied well in that population and therefore new prediction equations were developed. Schirmer and Wiltshire[14] in their study on Black South Africans found that the Moyers[2] prediction tables were not applicable to that population and they developed new prediction tables. There is inconclusive evidence of the applicability of the Tanaka and Johnston[1] equation and Moyers[2] tables in populations of African descent.

Both the Tanaka and Johnston[1] equation and Moyers[2] prediction tables use the four permanent mandibular incisors as the predictor teeth to estimate the combined mesiodistal tooth-widths of the unerupted permanent canine and premolars on one quadrant. This is due to the fact that they appear early during the mixed dentition period, are easy to measure both in the mouth and on dental casts and they are less prone to morphological changes.[6] However, the use of only the four permanent mandibular incisors as a predictor of the sum of mesiodistal tooth-widths of the unerupted canines and premolars has been shown not to give high correlation coefficients [3,4,10]. The inclusion of first permanent maxillary and mandibular molars to the four permanent mandibular incisors as predictor teeth has been shown to give higher correlation coefficients[3, 4]

The broad objective of this study was to measure the mesiodistal tooth-widths of permanent teeth in 13-17 year old Kenyans and compare measured values of sum of mesiodistal tooth-widths of permanent canines and premolars with predicted values of the same teeth obtained using two prediction equations.

1.1 LITERATURE REVIEW

This section will highlight what odontometric measurements are and their importance, the various methods of estimation of mesiodistal tooth-widths of unerupted permanent canines and premolars and also the whether the commonly used Tanaka and Johnston[1] equation can be used without modification in a Kenyan population.

1.1.1 Odontometric measurements

Odontometry is the anthropological science of measuring the size and proportion of teeth[15]. Odontometry forms the basis of all studies comparing measured and predicted values of mesiodistal tooth-widths[3,4,5]. These measurements in live patients can either be done directly in the mouth or impressions of the dental arches can be taken and measurements done on dental casts[6]. Measurements of teeth from human skeletons are also done[15]. Direct measurement of teeth in the mouth are more accurate but not reliable and thus measurements on dental casts are used commonly because of their better reliability[15]. Odontometric measurements can provide useful clinical information for both orthodontists and restorative dentists[16]. For example, in purchasing and stocking of commonly used molar band sizes in particular clinical settings in a specified population.

Data from odontometric studies enables various groups of teeth to be compared and for correlation coefficients to be determined especially in predicting the size of unerupted permanent teeth[3]. The correlation coefficients are then used to formulate regression equations[1]. Previous studies[1,3,4] have reported low to moderate correlation coefficients between the four permanent mandibular incisors and the mesiodistal tooth-widths of permanent canines and premolars. Ngesa[6] studied 131 dental casts of a Kenyan population and reported correlation coefficients of 0.610 and 0.750 for maxillary and mandibular permanent canines and premolars respectively. While Diagne et al[13] studied 50 dental casts and reported correlation coefficients of 0.68 and 0.73 for maxillary and mandibular permanent canines and premolars respectively. However, the inclusion of the first permanent molars in the regression equation has been reported to improve the correlation coefficient [3, 4, 5].

1.1.2 Estimation of mesiodistal tooth-widths of unerupted permanent canines and premolars

There are various methods:

- ***Radiographic methods***

  Radiographic methods involve the use of periapical films and cephalometric radiographs[8, 9, 10]. The use of the periapical fims requires the use of long cone X-ray tubes. This is in order to obtain the true size of the tooth. The long cone X-ray tube is either 16 inches[8] from the skin-target or 19 inches[9] from the intra-oral periapical film. The mesiodistal tooth-widths of the unerupted permanent canines and premolars are then measured from the resulting radiographs.

  The 45^{o} cephalometric radiograph has been reported to be the most precise method to predict the mesiodistal tooth-widths of unerupted permanent canines and premolars[3]. However, it is technique sensitive, time consuming, requires the use of sophisticated equipment and magnification correction[3, 20]. Therefore, it is not suitable for clinical use in the developing countries where resources are scarce.

  Some studies[10, 19] have described the use of 45^{o} cephalometric radiographs in estimating the mesiodistal tooth-widths of unerupted permanent canines and premolars. Mandibular casts and 45^{o} cephalometric radiographs were taken during the mixed dentition period before eruption of the permanent canines and premolars[10,19]. While in other studies, study casts and periapical radiographs of the unerupted permanent canines and premolars were taken at the mixed dentition stage[8]. When there was full permanent dentition the mesiodistal tooth-widths of the canines and premolars were measured from study casts. These measured values from were then compared to the measurements obtained from the radiographs after correcting for magnification[10]. The corrected radiographic measurements showed high correlation coefficients with the measured values from the study casts, Hixon and Oldfather[8] study was 0.870, de Paula et al[10] was 0.820 for males and 0.720 for females and Martinelli et al[19] was 0.840 . Linear regression equations were then developed to estimate the mesiodistal tooth-widths of permanent canines and premolars[8,10,19]. However, use of radiographs is technique sensitive and requires standardization; by using a cephalostat and a constant film to X-ray tube distance.

- ***Regression methods***

  Regression equations are mathematical equations that estimate the combined mesiodistal tooth-widths of a group of unerupted teeth using a defined set of predictor teeth[20]. These regression equations can either be single linear regression equations or multiple linear regression equations.

  Single linear regression equations (SLRE) involve the use of only one predictor variable, while multiple linear regression equations (MLRE) involve the use of more than one predictor variable[20, 42].

SLRE are typically represented as:

$y = a + bx$

Where:

y is the predicted size of canines and premolars in one quadrant

x is a single predictor variable for example, combined mesiodistal tooth-widths of the 4 mandibular incisors

a and ***b*** are constants customized to the population from which the equation was developed

MLRE are typically represented as:

$Y = B_o + B_1X_1 + B_2X_2 + ...B_iX_i$

Where

Y the predicted size of canines and premolars in one quadrant

$X_1, X_2...X_i$ are unique predictor variables

$B_o, B_1...B_2$ are constants

The Tanaka and Johnston[1] equation is the most commonly used prediction equation[5,13]. It is a simple linear regression that estimates the mesiodistal tooth-widths of the unerupted permanent canines and premolars for one quadrant. There are separate equations for the mandibular and maxillary arches. It is a simple and fairly straightforward method to use[3]. It is represented as:

Mesiodistal tooth-widths of maxillary canine and premolars in one quadrant=

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

Mesiodistal tooth-widths of mandibular canine and premolars in one quadrant =

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

The Tanaka and Johnston[1] equation was developed using a sample of North American Caucasian children. Several studies have shown that the Tanaka and Johnston[1] equation has to be modified when it is used in different ethnic and racial populations[3,4,5]. This is because of variation of tooth size among different races and ethnic groups[13, 14, 21]. Nourallah et al[5] reported that the Tanaka and Johnston[1] equation over-estimated the mesiodistal tooth-widths of canines and premolars in a Syrian (Arabic) population, necessitating the creation of new prediction equations. Buwembo et al[12] in a Ugandan population, Diagne et al[13] in a Senegalese population and Bernabé et al[21] in a Peruvian population, all found the Tanaka and Johnston[1] equation not applicable in their respective populations and thus had to develop new single linear regression equations.

The Tanaka and Johnston[1] equation uses the four permanent mandibular incisors as predictors[6, 13]. Various studies found that prediction methods using the four permanent mandibular incisors showed a low correlation between the predictors and mesiodistal tooth-widths of the canines and premolars[6]. However the four permanent mandibular incisors continue to be used because of ease of measurement, early eruption and constant morphology[6].

Studies have reported that the addition of the first permanent molars in developing prediction equations resulted in higher correlation coefficients than use of only the four mandibular permanent incisors[3,4,5]. Melgaço et al[3] reported that the correlation coefficients developed in their study closely approximated that produced by the radiographic method as described by Hixon and Oldfather[8].

Melgaço et al[3] equation:

$y = a + bx$

Where

y is the predicted sum of the mesiodistal tooth-widths in millimetres of the mandibular permanent canines and all premolars on both sides of the dental arch

x is the sum of the mesiodistal widths in millimetres of the four mandibular permanent incisors plus the mesiodistal tooth-widths of the two mandibular first permanent molars on both sides of the dental arch

a is a constant, the y-intercept. In males the value is 7, in females 9.2 and for both males and females 6.55.

b is a constant, it's the slope of the regression. In males the value is 0.824, in females 0.766 and for both males and females 0.829.

- ***Combination of radiographic methods and prediction equations***

Hixon and Oldfather[8] described a method combining the use of radiographs and prediction charts. The radiographs were obtained by use of long cone X-ray 16 inches from the skin-target. In this method, the sum of the mesiodistal tooth-widths of one permanent mandibular central incisor and lateral incisor obtained from study casts are added to the mesiodistal tooth-widths of the premolars from the same side obtained from the radiographs taken during the mixed dentition period. This is known as the *measured value.* This *measured* value is then used to estimate the sum of the mesiodistal tooth-widths of the permanent canines and premolars from prediction tables. The main drawback of this method is that it requires the use of radiographic equipment, radiographs produced might be of inadequate quality and the procedure is time consuming on the part of the dentist[6].

1.1.3 Applicability of tooth size prediction equations in the Kenyan population

The applicability of most commonly used non-radiographic prediction equations has not been investigated widely in African ethnic groups[6]. Only a few studies have been done to investigate the accuracy of Tanaka and Johnston[1] equation and Moyers[2] prediction tables in African populations[6,13].

Diagne et al[13] reported that the Tanaka and Johnston[1] equation did not accurately predict mesiodistal tooth-widths of the permanent canines and premolars in a Senegalese (black West African) population. This study reported correlation coefficients of 0.680 and 0.730 for the maxillary and mandibular canines and premolars respectively. A Kenyan study found that the prediction equation developed in that study did not vary greatly from the Tanaka and Johnston[1] equation and recommended the use of Tanaka and Johnston[1] equation in Kenyans of African descent[6]. The Kenyan study reported correlation coefficients of 0.610 and 0.750 for the maxillary and mandibular canines and premolars respectively[6].

The aim of this study was to measure the mesiodistal tooth-widths of permanent teeth from the right to the left first molar in both dental arches in 13-17 year old

Kenyans of African descent and to use these measured values to compare with predicted values of canines and premolars obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations.

CHAPTER TWO

2.0 RESEARCH PROBLEM

2.1 Statement of the problem

There have been few odontometric measurement studies done on Africans especially those to determine mesiodistal tooth-widths of permanent teeth[6,14]. Similarly there have been few studies to test the applicability of commonly used non-radiographic prediction equations in African populations[13, 14]. The commonly used Tanaka and Johnston[1] equation has been used in African populations despite it being based on a Caucasian population. Various studies have shown that it cannot be applied to non-Caucasian populations without being modified[5, 6, 13]. In addition, the Tanaka and Johnston[1] equation uses the four permanent mandibular incisors as predictor teeth and this gives moderate correlation coefficients. Inclusion of mandibular and maxillary first permanent molars to the four permanent mandibular incisors to be used as predictor teeth has been shown to give higher correlation coefficients[4]. The relationship of the predictor teeth and the sum of mesiodistal tooth-widths of canines and premolars was investigated in the present study to determine the correlation coefficients (Figure 2.1).

Mesiodistal tooth-widths
of the following teeth

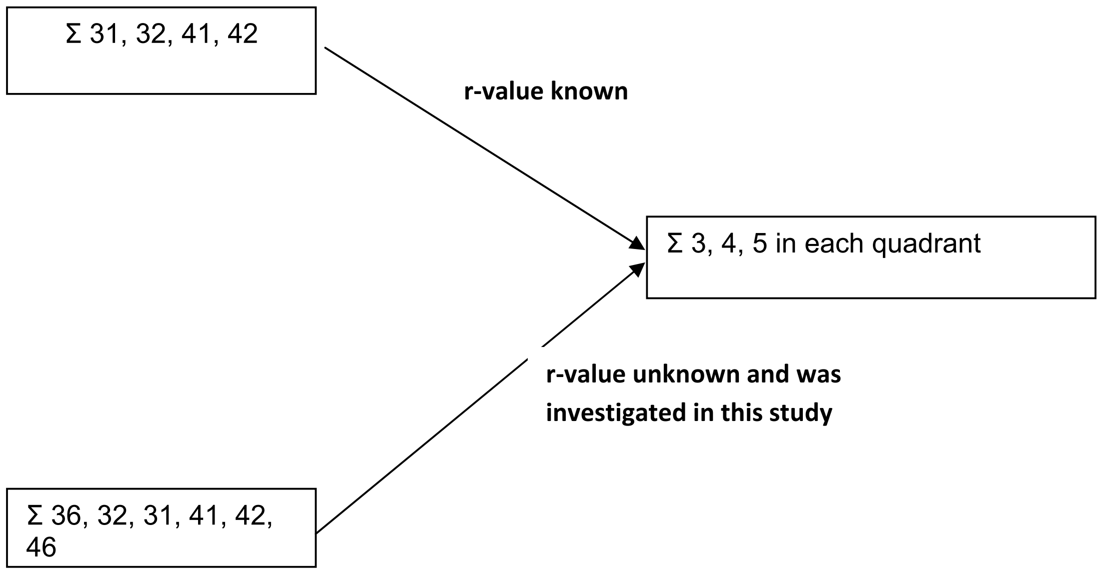

Figure 2.1: Conceptual framework. The illustration displays the various predictor teeth used to predict the mesiodistal tooth-widths of permanent canines and premolars, relationship between different predictor teeth, correlation coefficients and the mesiodistal tooth-widths of the canines and premolars. The correlation coefficient (r) between one set of predictor teeth and the mesiodistal tooth-widths of permanent canines and premolars is known, while the r value for the second set of predictor teeth was determined in this study.

2.2 Hypotheses

1. Null

   There is no significant difference in the actual (measured) and calculated (predicted) values of the sum of mesiodistal tooth-widths of the permanent canines and premolars using Tanaka and Johnston equation.

   There is no significant difference in the actual (measured) and calculated (predicted) values of the sum of mesiodistal tooth-widths of the permanent canines and premolars using Melgaço et al equation.

There is a significant difference in the sum of mesiodistal tooth-widths of the permanent canines and premolars obtained using Tanaka and Johnston equation with sum of mesiodistal tooth-widths obtained using Melgaço et al equation.

2. Alternate

There is a significant difference in the actual (measured) and calculated (predicted) values of the sum of mesiodistal tooth-widths of the permanent canines and premolars using Tanaka and Johnston equation.

There is a significant difference in the actual (measured) and calculated (predicted) values of the sum of mesiodistal tooth-widths of the permanent canines and premolars using Melgaço et al equation.

There is a significant difference in the sum of mesiodistal tooth-widths of the permanent canines and premolars obtained using Tanaka and Johnston equation with sum of mesiodistal tooth-widths obtained using the Melgaco et al equation.

2.3 Justification

There is scarcity of literature on odontometric measurements and prediction of mesiodistal tooth-widths of unerupted permanent canines and premolars on persons of African descent. There is only one previous Kenyan study[6] that obtained odontometric data. This previous study measured permanent teeth mesiodistal tooth-widths from the second premolar to the contra-lateral second premolar for both upper and lower arches. In addition, the teeth used as predictor teeth were the permanent mandibular incisors. In the present study, mesiodistal tooth-widths were measured from the permanent fist molar to the contra-lateral permanent first for both arches and the predictor teeth were the permanent mandibular incisors and the first permanent molars.

The present study obtained odontometric data and this added to the data from a previous Kenyan study[6] that also had odontometric measurements. These data can be used to calculate Kenyan population averages of mesiodistal tooth-widths which can be helpful to general dentists and orthodontists in space analysis.

These odontometric measurements can be used by both orthodontists and restorative dentists. Mesiodistal sizes of teeth are important for instance when selecting molar bands or when choosing stainless steel crowns for permanent first molars. Knowledge of the average mesiodistal tooth-widths for a given population makes the process of selection for the dentist easier. It also influences the purchase and stocking of dental materials that rely on mesiodistal tooth size.

Most prediction equations[1, 2] are based on data derived from Caucasian populations. Previous studies[3, 4, 5, 6] have shown racial and ethnic group differences in mesiodistal tooth-widths and prediction equations obtained from those data are not applicable to populations that are not Caucasian. They either over or under predict the mesiodistal tooth-widths of unerupted permanent canines and premolars. Therefore, the present study obtained odontometric data from Kenyans of African descent in order to formulate prediction equations most suitable to our population. These prediction equations can be used by the dentist in clinical decision making during the mixed dentition period to make treatment decisions including; serial extractions, guided eruption or monitoring[3].

A good prediction equation should have a correlation coefficient of not less than 0.6 to be considered clinically significant[20]. The correlation coefficient (r) shows the relationship between the actual (measured) and predicted (calculated) value. The Tanaka and Johnston[1] equation has moderate correlation coefficients of 0.648 and 0.625 for the mandibular and maxillary arches respectively. The Melgaço et al[3] equation has a high correlation coefficient of 0.810. The present study investigated correlation coefficient (r) of the Tanaka and Johnston[1] equation and whether the Melgaço et al[3] equation gave higher r values in predicting the mesiodistal tooth-widths of the unerupted mandibular permanent canines and premolars.

2.4 Objectives

2.4.1 Broad objective

To measure the mesiodistal tooth-widths of permanent teeth in 13-17 year old Kenyans of African descent and to use these values to compare with values of mesiodistal tooth-widths of the canines and premolars obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations.

2.4.2 Specific objectives

1. To measure mesiodistal tooth-widths of the permanent teeth from the right first molar to the left first molar of both maxillary and mandibular arches in Kenyans of African descent aged 13-17 years old.
2. To determine the sum of mesiodistal tooth-widths of the permanent canines and premolars using the Tanaka and Johnston[1] equation.
3. To determine the sum of mesiodistal tooth-widths of the permanent canines and premolars using the Melgaço et al[3] equation.

4. To compare actual (measured) sum of mesiodistal tooth-widths of permanent canines and premolars with sum of mesiodistal tooth-widths obtained using Tanaka and Johnston[1] equation.
5. To compare actual (measured) sum of mesiodistal tooth-widths of permanent canines and premolars with sum of mesiodistal tooth-widths obtained using the Melgaço et al[3] equation.
6. To compare sum of mesiodistal tooth-widths of the permanent canines and premolars obtained using the Tanaka and Johnston[1] equation with sum of mesiodistal tooth-widths obtained using the Melgaço et al[3] equation.

2.5 Variables

The variables investigated in this study are shown in Table 2.1.

Table 1: Variables and unit of measurement for each variable

Socio-demographic variables	
Age in years	
Gender (male/female)	
Independent variables	***Unit of measurement***
Sum of mesiodistal tooth-widths of four mandibular permanent incisors	Millimetres
Sum of mesiodistal tooth-widths of first permanent mandibular molars	Millimetres
Dependent variable	
Sum of mesiodistal tooth-widths of mandibular permanent canine and premolars	Millimetres

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Design

A descriptive cross-sectional study was carried out.

3.2 Study Area

The study was carried out in two secondary schools. These were Starehe Boys' Centre and Starehe Girls' Centre.

3.3 Study Population

The study population included 13-17 year old Kenyans of African descent with full permanent dentition.

3.3.1 Inclusion criteria

- Study participants were Kenyans of African descent.
- Study participants had all fully erupted permanent incisors, canines, premolars and first molars.
- Study participants had teeth free from caries, no interproximal restorations and no crown fractures.
- Study participants had teeth free from morphological anomalies.

3.3.2 Exclusion criteria

- Students who were Kenyan but not of African descent.
- Students who had retained primary or missing teeth.
- Students who had orthodontic treatment or were currently undergoing orthodontic treatment.

- Students with malocclusions which prevented accurate measurement of mesiodistal tooth-widths.

3.4 Sample size determination

The following assumptions were made based on assumptions from a previous Kenyan study[6]:

- Power is 80%
- Significance level at 5%
- Confidence interval of 0.2mm
- Standard error of mean of 0.2mm
- Confidence interval of 95%

The following Kirkwood and Sterne[18] formula was used:

$$n = \frac{(u + v)^2 \mu}{(\mu_1 - \mu_0)^2}$$

n is required sample size

u is the one sided percentage point of the normal distribution corresponding to 100% - the power

v is the percentage of the normal distribution corresponding to the required (2 sided) significance interval

μ is the confidence interval

$\mu_1 - \mu_0$ is the standard error of the mean/clinically important difference.

The formula was then applied:

$$n = \frac{(0.84 + 1.96)^2 \times 0.2}{(0.2)^2}$$

= 39.2

A contingency of 10% was added to ***39.2*** and a sample size of 43 was obtained.

Minimum number of study participants was ***43.***

This was the number of participants in each school. Therefore the total sample size required was ***86*** subjects.

3.5 Sampling procedure

The two schools were chosen by convenient sampling. The 13-17 year old age group was chosen because at this age, the permanent dentition is present. School records in both schools were used to establish the number of students who were 13-17 years old. Using the table of random numbers, students were randomly chosen to get the required sample size for this study.

3.6 Minimizing errors and bias

1. The investigator was calibrated by Dr Ngesa (supervisor) before actual data collection.
2. All measurements were conducted by the investigator.
3. The digital vernier calliper was calibrated prior to its use for the study at the Kenya Bureau of Standards (Appendix IX).
4. The study population was restricted to only those who met the inclusion criteria.
5. Randomization was achieved by selecting the subjects using simple random sampling.

3.7 Data collection instruments, technique and procedures

The investigator made impressions of both the maxillary and mandibular arches using an irreversible hydrocolloid impression material and perforated metallic dentate stock trays (Appendix VII).

The impressions were made in the medical clinic of the girls' school using natural light with the study subjects seated on normal chairs. In the boys' school, the impressions were made in the school's dental clinic on a dental chair using natural light. In both schools impressions were done during the lunch hour break and five students were seen in each session.

3.7.1 Hydrocolloid impressions

Both maxillary and mandibular arch impressions were made using perforated metallic dentate stock trays and irreversible hydrocolloid impression material-alginate (BLUEPRINT-DENTSPLY, DeTrey GmbH, Germany). The alginate material was manipulated according to the manufacturer's instructions.

The obtained impressions were rinsed under running tap water, wrapped with moist gauze and stored in a sealed polythene bag until they were poured in the dental laboratory of the School of Dental Sciences, University of Nairobi. Transfer of the impressions to the dental laboratory took on average one hour. A trained dental technician casted the impressions within 15 minutes of receiving them using type III dental stone to obtain dental casts. The dental stone was mixed according to the recommended powder to water ratio for all the impressions.

A pair of dental casts for each study participant was given a serial number corresponding to the serial number on the data capturing form (Appendix II).

3.7.2 Tooth-width measurements

All the mesiodistal tooth-widths from the first permanent molar to the antimeric first permanent molar in both mandibular and maxillary arches were measured from dental stone casts using an electronic digital vernier calliper (Masel, USA) (Appendix VIII). The beaks of the electronic digital vernier calliper were held perpendicular to the occlusal plane at the anatomical contact points of a tooth as described by Hunter and Priest[32] (Figure 2.1).

Each tooth was measured twice to the nearest 0.01mm; an average measurement was then calculated and entered on the data capturing form (Appendix VI).

Figure 3.1: Measuring mesiodistal tooth-width of a selected case

3.8 Reliability and validity

3.8.1 Validity

The digital vernier calliper was calibrated at the Kenya Bureau of Standards before being used.

All teeth were measured twice to the nearest 0.01mm and the average value used as the measure of a tooth. The two measurements did not differ by more than 0.02mm. All measurements were done in natural light and 3 pairs of dental casts were measured in each hour.

3.8.2 Reliability

The investigator did all the measurements under standardized conditions on the dental casts to eliminate inter-examiner variation. The investigator also measured five randomly selected casts twice for each gender one week apart to check on the intra-examiner variability. In collaboration with a qualified statistician from the School of Mathematics University of Nairobi, correlation coefficients were calculated for the intra-examiner measurements. The investigator was calibrated by one of his supervisors to standardise data collection and measurement of mesiodistal tooth-widths. The intra-class coefficients for both intra-examiner and inter-examiner measurements were 0.99 which were within the acceptable limits of 5%.

3.9 Data analysis

Data was entered in specially designed data capturing forms (Appendix VI) and then organised using Microsoft Excel software. It was then coded and transferred to Statistical Package for Social Sciences (SPSS) version 14.0 software for Windows for analysis. Exploration of the data for normality was done first and then subjected to the appropriate statistical tests.

Exploration and statistical analysis of the data was done as follows:

- Shapiro-Wilk test was done to test the data for normality.
- Paired t-test was done to examine bilateral symmetry of the mesiodistal tooth-widths of all the measured individual teeth and combined mesiodistal tooth-widths of the permanent canines and premolars.

- Pearson product-moment coefficient was used to evaluate the correlation between the groups of teeth.
- Independent t-test was used to compare data from male and female participants.
- Paired t-test was used to test whether there was any statistically significant difference between measured sum of mesiodistal tooth-widths of the permanent canines and premolars and values obtained using the Tanaka and Johnston[1] equation.
- Paired t-test was used to test whether there was any statistically significant difference between measured sum of mesiodistal tooth-widths of the permanent canines and premolars and values obtained using the Melgaço et al[3] equation.
- Paired t-test was used to test whether there was any statistically significant difference between sum of mesiodistal tooth-widths of the permanent canines and premolars obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations.

The results were presented in the form of tables (Table 3.1 to Table 3.18) and scatter plots (Figure 3.1 to Figure 3.5).

3.10 Ethical considerations

1. The proposal was submitted to the Ethics, Research and Standards committee at the Kenyatta National Hospital for approval of the study and ethical approval was obtained (Appendix I).
2. Permission and consent to carry out the study in the two secondary schools was obtained from the Ministry of Education (Appendix II).

3. Permission and consent to carry out the study was obtained from the administration of both Starehe Boys' and Girls' Centres (Appendix III and IV).
4. Each study participant gave informed consent (Appendix V).

CHAPTER FOUR

4.0 RESULTS

4.1 Age and gender

Sixty eight secondary school students participated in this study, 40 females and 28 males. The mean age of females was 14.65 years (SD; 1.21 years) and males 14.89 years (SD; 1.23 years).

4.2 Accuracy of measurements

The intra-class coefficient between two different measurements made on the same casts at different times by the investigator and one of his supervisors was 0.99, this was within the acceptable limits of 5%.

4.3 Mesiodistal tooth-width measurements

The means, ranges, standard deviations in millimetres (mm) and co-efficient of variation of the mesiodistal tooth-widths in each dental arch were calculated. They are presented in Tables 4.1 and 4.2 for males and females separately and the combined sample.

Table 4.1 shows the descriptive statistics for the mandibular teeth for male and female participants and the combined sample. For the males, there was greatest dispersion in mesiodistal tooth-widths of the second premolars for both sides (SD; 0.78 mm right; 0.77 mm left) and the least dispersion in both central incisors (SD; 0.36 mm). The right second premolar showed the greatest variability with a coefficient of variation (CV) of 10.69% and the right first permanent molar had the least variability with a CV of 6.29%. For the females, there was greatest dispersion in mesiodistal tooth-widths of the mandibular first molar in both sides (SD; 0.62 mm), the least dispersion in the left central incisor (SD; 0.41 mm), greatest variability in the right central incisor with a CV of 8.87% and least variability in the first permanent molar with a CV of 5.67%. For the combined sample, there was greatest dispersion for the first permanent molar (SD; 0.70 mm right; 0.71 mm, left), the least dispersion for the central incisors (SD; 0.41mm right; 0.39mm left), greatest variability for the right second premolar with a CV of 9.38% and least variability for the right first permanent molar with a CV of 6.29%.

Table 4.1: Mandibular mesiodistal tooth-widths (in mm) for male and female participants (n=68)

Tooth type	Gender (Males, n=28 Females, n=40)	Right Side				Left side			
		#***Mean (mm)***	Range	*SD (mm)	*CV (%)	#***Mean (mm)***	Range	*SD (mm)	*CV (%)
Central incisors	Male	***5.09***	4.58-5.87	±0.36	7.02	***5.11***	4.45-5.85	±0.36	7.10
	Female	***4.99***	4.12-6.16	±0.44	8.87	***5.00***	4.01-6.00	±0.41	8.27
	Male and female	***5.03***	4.12-6.16	±0.41	8.14	***5.05***	4.01-6.00	±0.39	7.81
Lateral incisors	Male	***5.73***	4.98-6.74	±0.40	7.03	***5.73***	4.93-6.63	±0.46	8.05
	Female	***5.65***	4.56-6.68	±0.46	8.23	***5.60***	4.89-6.73	±0.45	8.07
	Male and female	***5.69***	4.56-6.74	±0.44	7.73	***5.65***	4.89-6.73	±0.47	8.08
Canine	Male	***7.15***	6.33-8.27	±0.48	6.72	***7.15***	6.43-8.53	±0.52	7.28
	Female	***6.56***	5.60-7.54	±0.46	7.00	***6.65***	5.78-7.56	±0.44	6.57
	Male and female	***6.80***	5.60-8.27	±0.55	8.05	***6.85***	5.78-8.53	±0.53	7.75
First premolar	Male	***7.39***	5.97-8.89	±0.72	9.69	***7.38***	6.28-8.55	±0.62	8.42
	Female	***7.11***	6.07-7.99	±0.49	6.88	***7.23***	6.09-8.13	±0.52	7.17
	Male and female	***7.23***	5.97-8.89	±0.60	8.35	***7.29***	6.09-8.55	±0.56	7.73
Second premolar	Male	***7.33***	5.67-8.90	±0.78	10.69	***7.48***	6.00-9.77	±0.77	10.33
	Female	***7.05***	5.54-8.21	±0.56	8.00	***7.19***	5.62-8.54	±0.58	8.09
	Male and female	***7.17***	5.54-8.90	±0.67	9.38	***7.31***	5.62-9.77	±0.68	9.25
First permanent molar	Male	***11.45***	10.39-13.03	±0.72	6.29	***11.41***	10.04-13.01	±0.76	6.63
	Female	***10.96***	9.71-12.56	±0.62	5.67	***10.95***	9.76-12.45	±0.62	5.70
	Male and female	***11.16***	9.71-13.03	±0.70	6.29	***11.15***	9.76-13.01	±0.71	6.40

*CV: co-efficient of variation, SD: standard deviation

#The mean mesiodistal tooth-widths are generally larger in males than females

Table 4.2 shows the descriptive statistics for the maxillary teeth for male and female participants and the combined sample. For males there was greatest dispersion for the left central incisors (SD; 0.89 mm) and the least dispersion for the left canines (SD; 0.41 mm), while there was greatest variability for the left central incisor with a CV of 10.30% and the least variability left canine with a CV of 5.17%.

For females, there was greatest dispersion in the left first permanent molar (SD; 0.68), the least dispersion for the right canine (SD; 0.43 mm), greatest variability in the right second premolar with a CV of 8.25% and least variability of the right canine with a CV of 5.75%. For the combined sample, there was greatest dispersion for the first permanent molars (SD; 0.72 mm right; 0.78 mm left), the least dispersion for the first premolar (SD; 0.50mm right; 0.48mm left), greatest variability for the left central incisor with a CV of 8.44% and least variability for the left first premolar with a CV of 6.56%.

Table 4.2: Maxillary mesiodistal tooth-widths (in mm) for male and female participants (n=68)

Tooth type	Gender (Males, n=28 Females, n=40)	Right side				Left side			
		#***Mean (mm)***	Range	*SD (mm)	*CV (%)	#***Mean (mm)***	Range	*SD (mm)	*CV (%)
Central incisors	Male	***8.72***	7.93-10.33	±0.64	7.29	***8.64***	5.56-10.17	±0.89	10.30
	Female	***8.36***	7.16-11.02	±0.69	8.22	***8.44***	7.52-9.84	±0.57	6.76
	Male and female	***8.51***	7.16-11.02	±0.69	8.06	***8.52***	5.56-10.17	±0.72	8.44
Lateral incisors	Male	***6.89***	6.09-8.11	±0.52	7.50	***6.90***	5.15-8.38	±0.59	8.57
	Female	***6.60***	5.33-7.86	±0.51	7.76	***6.61***	5.55-7.60	±0.52	7.94
	Male and female	***6.72***	5.33-8.11	±0.53	7.91	***6.73***	5.15-8.38	±0.57	8.42
Canine	Male	***7.97***	7.06-9.30	±0.54	6.77	***7.95***	7.34-9.13	±0.41	5.17
	Female	***7.42***	6.40-8.40	±0.43	5.75	***7.36***	6.33-8.44	±0.44	6.01
	Male and female	***7.65***	6.40-9.30	±0.55	7.14	***7.60***	6.33-9.13	±0.52	6.80
First premolar	Male	***7.42***	6.50-8.55	±0.51	6.91	***7.40***	6.72-8.40	±0.46	6.27
	Female	***7.25***	6.01-8.29	±0.48	6.66	***7.19***	5.77-8.45	±0.47	6.57
	Male and female	***7.32***	6.01-8.55	±0.50	6.81	***7.28***	5.77-8.45	±0.48	6.56
Second premolar	Male	***6.88***	6.00-8.14	±0.53	7.65	***6.89***	6.18-8.40	±0.50	7.28
	Female	***6.60***	5.38-7.64	±0.54	8.25	***6.55***	5.82-7.66	±0.45	6.91
	Male and female	***6.71***	5.38-8.14	±0.55	8.23	***6.70***	5.82-8.40	±0.50	7.45
First permanent molar	Male	***10.68***	8.57-11.98	±0.75	6.99	***10.52***	8.05-11.86	±0.88	8.34
	Female	***10.35***	9.04-11.89	±0.67	6.49	***10.18***	8.93-11.77	±0.68	6.64
	Male and female	***10.49***	8.57-11.98	±0.72	6.84	***10.32***	8.05-11.86	±0.78	7.53

*CV: co-efficient of variation, SD: standard deviation

#The mean mesiodistal tooth-widths are generally larger in males than females

Table 4.3 shows the comparison of mean mesiodistal tooth-widths from the present investigation compared to other studies done on two different ethnic groups. The Southern Chinese had the greatest mesiodistal tooth-widths while the present study were generally larger than those of the North American Whites.

Table 4.3: Comparison of mean mesiodistal tooth-widths (in mm) between present and other studies

Tooth type	***Gender M=male F=female***	***Present study 2011 (Kenyans of African descent)***	***Ling and Wong[27] 2006 (Southern Chinese)***	***Moorreess[17] 1957 (North American Whites)***
****Mandibular Arch***				
Central incisor	M	5.10	5.62	5.42
	F	5.00	5.57	5.25
Lateral incisor	M	5.73	6.22	5.95
	F	5.62	6.14	5.78
Canine	M	7.15	7.31	6.96
	F	6.60	6.89	6.47
First premolar	M	7.38	7.58	7.07
	F	7.17	7.36	6.87
Second premolar	M	7.41	7.56	7.29
	F	7.12	7.35	7.02
First molar	M	11.43	-	11.18
	F	10.96	-	10.74
****Maxillary Arch***				
Central incisor	M	8.63	8.85	8.78
	F	8.40	8.69	8.40
Lateral incisor	M	6.90	7.36	6.64
	F	6.60	7.18	6.47
Canine	M	7.96	8.30	7.95
	F	7.39	7.92	7.53
First premolar	M	7.41	7.77	7.01
	F	7.22	7.57	6.85
Second premolar	M	6.89	7.26	6.82
	F	6.57	7.10	6.62
First molar	M	10.60	-	10.81
	F	10.27	-	10.52

*Mean mesiodistal tooth-widths of right and left quadrants

Table 4.4 shows the comparison of mean mesiodistal tooth-widths of groups of teeth from the present investigation and those from other studies. The present and Jordanian studies had generally smaller mesiodistal tooth-widths while the South African study had the largest mesiodistal tooth-widths.

Table 4.4: Comparison of mean mesiodistal tooth-widths (in mm) of groups of teeth between present and other studies

Groups of teeth	***Gender M=male F=female***	***Present study 2011 (Kenyans of African descent)***	***Jaroontham and Godfrey[26] 2000 (Thai)***	***Al-Bitar et al[28] 2008 (Jordanian)***	***Schirmer and Wiltshire[14] 1997 (Black South Africans)***	***Philip et al[31] 2010 (Indian)***
Mandibular incisors	M	21.66 ± 1.62	23.89 ± 1.37	23.20 ± 0.34	23.92 ± 1.90	24.03 ± 1.05
	F	21.24 ± 1.35	23.23 ± 1.26	22.80 ± 0.31	23.66 ± 1.59	23.48 ± 0.93
Mandibular canine and premolars	M	21.94 ± 1.63	22.31 ± 1.03	21.60 ± 0.70	23.45 ± 1.37	22.50 ± 1.09
	F	20.90 ± 1.26	21.77 ± 1.26	20.70 ± 0.42	22.20 ± 1.24	21.99 ± 0.95
Maxillary canine and premolars	M	22.25 ± 1.16	23.16 ± 1.04	21.90 ± 1.47	23.22 ± 1.11	23.23 ± 1.07
	F	21.18 ± 1.16	22.64 ± 1.00	21.20 ± 1.13	22.28 ± 1.28	22.75 ± 0.94

The mean mesiodistal tooth-widths from the present study are generally smaller than for the other studies except for the mandibular canines and premolars

4.4 Bilateral symmetry of mesiodistal tooth-widths

Shapiro-Wilk test confirmed normality of the data and therefore paired t-test was performed to check for symmetry. Symmetry of mesiodistal tooth-widths between the right and the left sides for both maxillary and mandibular arches was assessed. The test was done separately for the males and females and for the combined sample.

Table 4.5 shows the results of the comparison of bilateral symmetry in males. There were statistically significant differences (p≤ 0.05) of 0.04 and 0.03 in mandibular second premolars and maxillary first permanent molars respectively.

Table 4.5: Comparison (paired t test) of mesiodistal tooth-widths (in mm) of antimeric teeth for males (n=28)

Tooth type	***Maxillary teeth***				***Mandibular teeth***			
	Absolute mean difference (mm)	****SD (mm)***	***t value***	****p value***	***Absolute mean difference (mm)***	****SD (mm)***	***t value***	****p value***
Central incisor	0.09	±0.92	0.52	0.61	0.03	±0.25	-0.54	0.59
Lateral incisor	0.01	±0.32	-0.09	0.93	0.01	±0.36	0.14	0.89
Canine	0.03	±0.36	0.37	0.71	0.00	±0.23	-0.09	0.93
First premolar	0.01	±0.30	0.26	0.80	0.01	±0.29	0.21	0.83
Second premolar	0.01	±0.36	-0.12	0.91	0.15	±0.35	-2.21	***0.04***¶
First permanent molar	0.16	±0.36	2.29	***0.03***¶	0.04	±0.22	0.95	0.35

*p≤ 0.05, SD; standard deviation

¶There were statistically significant differences in the mesiodistal tooth-widths for the contralateral mandibular second premolars and maxillary first permanent molars

Table 4.6 shows the results of the comparison of bilateral symmetry in females. There were statistically significant differences ($p \leq 0.05$) of 0.04, 0.00 and 0.05 for the maxillary first permanent molar, mandibular first and second premolars respectively.

Table 4.6: Comparison (paired t test) of mesiodistal tooth-widths (in mm) for antimeric teeth for females (n=40)

Tooth type	***Maxillary teeth***				***Mandibular teeth***			
	Absolute mean difference (mm)	****SD (mm)***	***t value***	****p value***	***Absolute mean difference (mm)***	****SD (mm)***	***t value***	****p value***
Central incisor	0.08	±0.36	-1.33	0.19	0.02	±0.28	-0.45	0.66
Lateral incisor	0.02	±0.33	-0.36	0.72	0.05	±0.19	1.75	0.09
Canine	0.06	±0.31	1.27	0.21	0.09	±0.31	-1.85	0.07
First premolar	0.06	±0.26	1.41	0.17	0.12	±0.25	-2.91	***0.00***¶
Second premolar	0.04	±0.28	0.83	0.41	0.14	±0.43	-2.06	***0.05***¶
First permanent molar	0.17	±0.49	0.17	***0.04***¶	0.00	±0.30	0.10	0.92

*$p \leq 0.05$, SD; standard deviation

¶There were statistically significant differences in the mesiodistal tooth-widths for the contralateral mandibular first and second premolars and maxillary first permanent molars

Table 4.7 shows the results of the comparison of bilateral symmetry for the combined sample. There were statistically significant differences ($p \leq 0.05$) of 0.00 and 0.00 in the mandibular second premolar and maxillary first permanent molar respectively.

Table 4.7: Comparison (paired t test) of mesiodistal tooth-widths (in mm) of antimeric teeth for combined sample (n=68)

Tooth type	***Maxillary teeth***				***Mandibular teeth***			
	Absolute mean difference (mm)	****SD (mm)***	***t value***	****p value***	***Absolute mean difference mm)***	****SD (mm)***	***t value***	****p value***
Central incisor	0.00	±0.65	-0.10	0.92	0.02	±0.26	-0.69	0.50
Lateral incisor	0.01	±0.32	-0.34	0.74	0.04	±0.27	1.07	0.29
Canine	0.05	±0.33	1.17	0.25	0.05	±0.28	-1.60	0.11
First premolar	0.04	±0.28	1.21	0.23	0.06	±0.27	-1.92	0.06
Second premolar	0.02	±0.31	0.49	0.63	0.14	±0.39	-2.97	***0.00***¶
First permanent molar	0.16	±0.44	3.05	***0.00***¶	0.02	±0.27	0.59	0.56

*$p \leq 0.05$, SD; standard deviation

¶There were statistically significant differences in the mesiodistal tooth-widths for the contralateral mandibular second premolars and maxillary first permanent molars

Table 4.8 shows the results of the comparison of bilateral symmetry of the sum of mesiodistal tooth-widths of the permanent canines and premolars for the mandibular and maxillary arches in males. There were no statistically significant differences ($p \leq 0.05$) of 0.11 and 0.74 in the mandibular and maxillary arches respectively.

Table 4.8: Comparison (paired t test) of the sum of mesiodistal tooth-widths (in mm) of permanent canines, first and second premolars for males (n=28)

Groups of teeth	***Absolute mean difference (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular Σ3,4,5	0.14	±0.44	***0.11***	-1.66
Maxillary Σ3,4,5	0.03	±0.52	***0.74***	0.33

*p≤ 0.05, SD: standard deviation

Table 4.9 demonstrates the results of comparison of bilateral symmetry of the sum of mesiodistal tooth-widths of the permanent canines and premolars for the mandibular and maxillary arches in females. There were statistically significant differences ($p \leq 0.05$) of 0.00 and 0.04 for the mandibular and maxillary arches respectively.

Table 4.9: Comparison (paired t test) of the sum of mesiodistal tooth-widths (in mm) of permanent canines, first and second premolars for females (n=40)

Groups of teeth	***Absolute mean difference (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular Σ3,4,5	0.35	±0.63	***0.00***	-3.49
Maxillary Σ3,4,5	0.16	±0.47	***0.04***	2.12

*p≤ 0.05, SD; standard deviation

Table 4.10 illustrates the comparison of bilateral symmetry of the sum of mesiodistal tooth-widths of the permanent canines and premolars for the mandibular and maxillary arches in the combined sample. There was a statistically significant difference ($p \leq 0.05$) of 0.00 in the mandibular arch and no statistically significant difference of 0.08 in the maxillary arch.

Table 4.10: Comparison (paired t test) of the sum of mesiodistal tooth-widths (in mm) of permanent canines, first and second premolars for the combined sample (n=68)

Groups of teeth	***Absolute mean difference (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular Σ3,4,5	0.26	±0.56	***0.00***	-3.81
Maxillary Σ3,4,5	0.11	±0.49	***0.08***	1.78

*p≤ 0.05, SD; standard deviation

4.5 Gender comparisons of mesiodistal tooth-widths

Shapiro-Wilk test confirmed normality of the data. Therefore, independent t-test was performed to assess the difference in mesiodistal tooth-widths between males and females.

Table 4.11 shows the results of the comparison of mean mesiodistal tooth-widths between the right and left sides for the mandibular teeth in males and females. Males statistically had larger teeth than females. However, there were statistically significant differences (p≤ 0.05) of 0.00 and 0.00 in the canine and first permanent molar respectively.

Table 4.11: Comparison (independent t test) of the mean mesiodistal tooth-widths (in mm) of the right and left mandibular teeth between male and female participants (n=68)

Tooth type	***Gender M=male F=female***	***N***	***Mean of right and left sides (mm)***	****SD(mm)***	****p value***	***t value***
Central incisor	M	28	5.10	±0.34	0.27	-1.11
	F	40	5.00	±0.41		
Lateral incisor	M	28	5.73	±0.39	0.32	-1.01
	F	40	5.62	±0.45		
Canine	M	28	7.15	±0.49	***0.00***¶	-4.91
	F	40	6.60	±0.42		
First premolar	M	28	7.38	±0.65	0.13	-1.52
	F	40	7.17	±0.49		
Second Premolar	M	28	7.41	±0.76	0.08	-1.81
	F	40	7.12	±0.53		
First permanent molar	M	28	11.43	±0.73	***0.00***¶	-2.93
	F	40	10.96	±0.60		

*p≤ 0.05, SD: standard deviation

Table 4.12 shows the results of the comparison of mean mesiodistal tooth-widths between the right and left sides for the maxillary teeth between males and females. Males statistically had larger teeth than females. However, there were statistically significant differences ($p \leq 0.05$) of 0.02 and 0.00 in the lateral incisor and canine respectively.

Table 4.12: Comparison (independent t test) of the mean mesiodistal tooth-widths (in mm) of the right and left maxillary teeth between male and female participants (n=68)

Tooth type	***Gender M=male F=female***	***n***	***Mean of right and left sides (mm)***	****SD(mm)***	****p value***	***t value***
Central incisor	M	28	8.63	±0.62	0.07	-1.85
	F	40	8.40	±0.60		
Lateral incisor	M	28	6.90	±0.53	***0.02***	-2.35
	F	40	6.60	±0.49		
Canine	M	28	7.96	±0.44	***0.00***	-5.48
	F	40	7.39	±0.41		
1st premolar	M	28	7.41	±0.47	0.10	-1.68
	F	40	7.22	±0.46		
2nd premolar	M	28	6.89	±0.48	0.10	-2.65
	F	40	6.57	±0.48		
1st Permanent molar	M	28	10.60	±0.79	0.06	-1.93
	F	40	10.27	±0.63		

*$p \leq 0.05$, SD; standard deviation

Table 4.13 presents the results of comparison of sum of mesiodistal tooth-widths of incisors between males and females for the mandibular and maxillary arches. Males had generally larger sums of mesiodistal tooth-widths of incisors than females. However, there was a statistically significant difference ($p \leq 0.05$) of 0.03 in the maxillary incisors and no statistically significant difference ($p \leq 0.05$) of 0.27 in the mandibular incisors.

Table 4.13: Comparison (independent t test) of sum of mesiodistal tooth-widths (in mm) of incisors between male and female participants (n=68)

Dental arch	***Gender***	***n***	***Mean (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular	Male	28	21.66	±1.63	***0.27***	-1.11
	Female	40	21.24	±1.35		
Maxillary	Male	28	31.15	±2.13	***0.03***	-2.30
	Female	40	30.00	±1.95		

*p≤ 0.05, SD; standard deviation

Table 4.14 shows the results of comparison of the sum of mesiodistal tooth-widths of the permanent canine and premolars between males and females for the mandibular and maxillary arches. Males had larger sums of mesiodistal tooth-widths of permanent canines and premolars than females. However, statistically significant differences ($p \leq 0.05$) of 0.00 and 0.00 were found in both mandibular and maxillary arches.

Table 4.14: Comparison (independent t test) of mesiodistal tooth-widths (in mm) for the sum of permanent canine, first and second premolars between male and female participants (n=68)

Dental arch	***Gender***	***N***	***Mean (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular	Male	28	21.94	±1.63	***0.00***	-2.96
	Female	40	20.90	±1.26		
Maxillary	Male	28	22.25	±1.16	***0.00***	-3.77
	Female	40	21.18	±1.16		

*p≤ 0.05, SD; standard deviation

Males had generally larger sums of mesiodistal tooth-widths of the permanent canine and premolars than females and statistically significant differences were found in the both the mandibular and maxillary arches.

4.6 Comparison of regression equations

Table 4.15 shows the comparison between the measured sum of mesiodistal tooth-widths of permanent canines and premolars and predicted values obtained using the Tanaka and Johnston[1] equation. There were no statistically significant differences ($p \leq 0.05$) of 0.47 and 0.49 in the mandibular and maxillary arches respectively.

Table 4.15: Measured sum of mesiodistal tooth-widths (in mm) of permanent canines and premolars compared (paired t test) with predicted values of the same teeth using Tanaka and Johnston[1] equation for the combined sample (n=68)

Dental arch and teeth	***Actual (measured) ± SD***	***Tanaka and Johnston[1] ± SD***	***Absolute mean difference (mm)***	****SD (mm)***	****p value***	***t value***
Mandibular canines and premolars	21.33 ±1.50	21.20 ±0.76	0.12	±1.33	***0.47***	0.73
Maxillary canines and premolars	21.62 ± 1.27	21.70 ± 0.76	0.09	±0.12	***0.49***	-0.70

*p≤ 0.05, SD; standard deviation

Table 4.16 demonstrates the comparison between the measured sum of mesiodistal tooth-widths of mandibular permanent canines and premolars and predicted values obtained using the Melgaço et al[3] equation. There were no statistically significant differences ($p \leq 0.05$) of 0.71 and 0.13 in both males and females respectively.

Table 4.16: Measured mesiodistal tooth-widths (in mm) for mandibular permanent canines and premolars compared (paired t test) with predicted values of the same teeth using Melgaço et al[3] equation (n=68)

Tooth type and gender	*Actual (measured) ±SD*	*Melgaço et al[3] (predicted) ±SD*	*Absolute mean difference (mm)*	**SD (mm)*	**p value*	*t value*
Combined values for canines and premolars in males (n=28)	43.87 ± 3.26	43.69 ± 1.71	0.18	±2.51	***0.71***	-0.38
Combined values for canines and premolars in females (n=40)	41.80 ± 2.51	42.26 ± 2.00	0.46	±1.88	***0.13***	1.55
Combined values for canines and premolars in both males and females (n=68)	42.65 ± 3.00	42.85 ± 2.00	0.20	±2.17	***0.45***	0.75

*$p \leq 0.05$, SD; standard deviation

Table 4.17 shows the comparison of sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations. There were statistically significant differences ($p \leq 0.05$) of 0.00 and 0.00 in males and the combined sample respectively and no statistically significant difference ($p \leq 0.05$) of 0.90 in females.

Table 4.17: Comparison (paired t test) of the sum of mesiodistal tooth-widths (in mm) of mandibular permanent canines and premolars obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations (n=68)

Gender	***Tanaka and Johnston[1] ±SD***	***Melgaço et al[3] ± SD***	***Absolute mean difference (mm)***	****SD (mm)***	****p value***	***t value***
Males (n=28)	42.66 ± 1.35	43.69 ± 1.71	1.03	±1.20	***0.00***	4.54
Females (n=40)	42.24 ± 1.63	42.26 ± 2.00	0.01	±0.73	***0.90***	0.13
Males and females (n=68)	42.41 ± 1.53	42.84 ± 2.00	0.43	±1.07	***0.00***	-3.35

*p≤ 0.05, SD; standard deviation

Tanaka and Johnston[1] equation values were multiplied by two to represent both quadrants of the mandibular arch as in the Melgaço et al[3] equation.

Table 4.18 illustrates the Pearson correlation coefficients of different groups of predictor teeth and the sum of mesiodistal tooth-widths of permanent canines and premolars for both mandibular and maxillary arches. The predictor teeth were; the four permanent mandibular incisors and the four permanent mandibular incisors and first permanent molars. The correlation coefficients for the sum of the four permanent mandibular incisors were 0.464 and 0.605 for the mandibular and maxillary arches respectively. The correlation coefficients for the sum of the four permanent mandibular incisors and first permanent molars were; 0.652, 0.674, 0.678 for males, females and the combined sample respectively in the mandibular arch.

Table 4.18: Correlation coefficients of different groups of predictor teeth and sum of mesiodistal tooth-widths of canines and premolars in the present study

Groups of predictor teeth	***r values***		
	Males	***Females***	***Males and females***
Mandibular arch			
Four mandibular incisors	0.339	0.550	0.464
Four mandibular incisors and two first mandibular molars	0.652	0.674	0.678
Maxillary arch			
Four mandibular incisors	0.578	0.630	0.605
Four mandibular incisors and two first mandibular molars	0.725	0.718	0.741

Inclusion of the two permanent mandibular molars to the four permanent mandibular incisors gave higher correlation coefficients.

Table 4.19 shows the regression parameters for the single linear regression equations used to estimate the sum of mesiodistal tooth-widths of the permanent mandibular canines and premolars when the four permanent mandibular incisors were used as predictor teeth. The coefficient of determination (r^2) shows the predictive accuracy of the regression equation to predict the sum of mesiodistal tooth-widths of the permanent mandibular canines and premolars based on the predictor teeth[6, 20].

Table 4.19: Regression parameters for the prediction equations of the sum of mesiodistal tooth-widths of canines and premolars using the four permanent mandibular incisors as predictor teeth

Gender				***Regression coefficient***		
	Tooth group	***r***	***r^2***	***a***	***b***	***Standard error of estimate***
Males (n=28)	Mandibular Σ3,4,5	0.339	0.115	13.078	0.409	1.564
	Maxillary Σ3,4,5	0.578	0.334	11.557	0.494	0.961
Females (n=40)	Mandibular Σ3,4,5	0.550	0.302	11.897	0.424	1.064
	Maxillary Σ3,4,5	0.630**	0.397	11.643	0.449	0.914
Males and females (n=68)	Mandibular Σ3,4,5	0.464	0.216	11.535	0.457	1.340
	Maxillary Σ3,4,5	0.605**	0.366	10.862	0.503	1.02

**The clinically significant single linear regression equations developed from these regression parameters are for the maxillary arch for the female and combined samples.

Table 4.20 demonstrates the regression parameters for the single linear regression equations used to estimate the sum of mesiodistal tooth-widths of the permanent mandibular canines and premolars when the four permanent mandibular incisors and two first molars were used as predictor teeth.

Table 4.20: Regression parameters for the prediction equations of the sum of mesiodistal tooth-widths of canines and premolars using the four permanent mandibular incisors and first permanent molars as predictor teeth

Gender				***Regression coefficient***		
	Tooth group	****r***	r^2	***a***	***b***	***Standard error of estimate***
Males (n=28)	Mandibular Σ3,4,5	0.652	0.425	-1.638	1.022	2.521
Females (n=40)	Mandibular Σ3,4,5	0.674	0.455	13.705	0.651	1.880
Males and females (n=68)	Mandibular Σ3,4,5	0.678	0.459	6.762	0.821	2.226

*All the single linear regression equations developed from these regression parameters are clinically significant.

Table 4.21 shows comparison of correlation coefficients obtained in the present study with those obtained from other studies. When using the mandibular permanent incisors as predictor teeth, the present study has the least correlation coefficient. However when the mandibular permanent incisors and first molars are used, the correlation coefficients obtained are all clinically significant and comparable to those of the other studies.

Table 4.21: Comparison of correlation coefficients from various studies for males, females and combined (males and females)

Study year and populations	***Dental Arch***	***Predictor teeth***	***Male***	***Female***	***Combined***
Present 2013 Kenyans of African descent	Mandibular	41,42,31,32, 36,46	0.652	0.674	0.678
	Mandibular	41,42,31,32	0.339	0.550	0.464
	Maxillary	41,42,31,32, 36,36	0.725	0.718	0.741
	Maxillary	41,42,31,32	0.578	0.630	0.605
Buwembo et al[24] 2012 Ugandans of African descent	Mandibular	41,42,31,32	0.790	0.840	0.830
	Maxillary	41,41,31,32	0.770	0.790	0.780
Diagne et al[13] 2003 Senegalese of African descent	Mandibular	41,42,31,32	0.730	0.630	0.730
	Maxillary	41,42,31,32	0.680	0.510	0.680
Tanaka and Johnson[1] 1974 White Americans	Mandibular	41,42,31,32	-	-	0.648
	Maxillary	41,42,31,32	-	-	0.625
Melgaço et al[3] 2007 White Brazilians	Mandibular	41,42,31,32, 36,46	0.795	0.774	0.810
Al-Bitar[28] et al 2007 Jordanian	Mandibular	41,42,31,32	0.650	0.680	0.660
		41,42,31,32	0.570	0.610	0.600
Philip et al[31] 2010 Indian	Mandibular	41,42,31,32	0.680	0.670	-
	Maxillary	41,42,31,32	0.660	0.650	-
Yuen et al[30] 1998 Hong Kong Chinese	Mandibular	41,42,31,32	0.770	0.690	-
	Maxillary	41,42,31,32	0.790	0.650	-

The Melgaço et al[3] and Buwembo et al[24] studies had the highest correlation coefficients

Figure 4.1 shows the graphic comparison between the sum of measured mesiodistal tooth-widths of the canines and premolars and predicted values obtained using the Tanaka and Johnston[1] equation for the maxillary arch. The Tanaka and Johnston[1] equation overestimated the sum of mesiodistal tooth-widths of the canines and premolars.

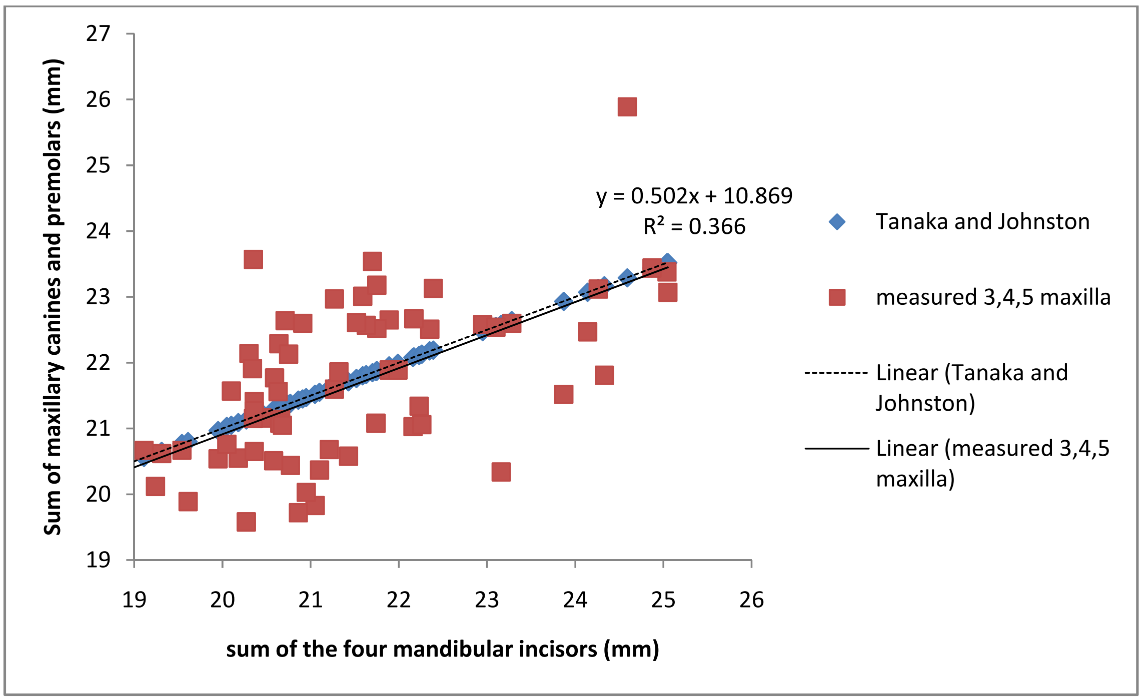

Figure 4.1: Graph illustrating comparison of sum of measured mesiodistal tooth-widths of maxillary canines and premolars with predicted values obtained using Tanaka and Johnston[1] equation

Figure 4.2 shows the graphic comparison between the sum of measured mesiodistal tooth-widths of the canines and premolars and predicted values obtained using the Tanaka and Johnston[1] equation for the mandibular arch. The Tanaka and Johnston[1] equation underestimates the sum of mesiodistal tooth-widths of the canines and premolars for sum of mandibular incisors below 24mm.

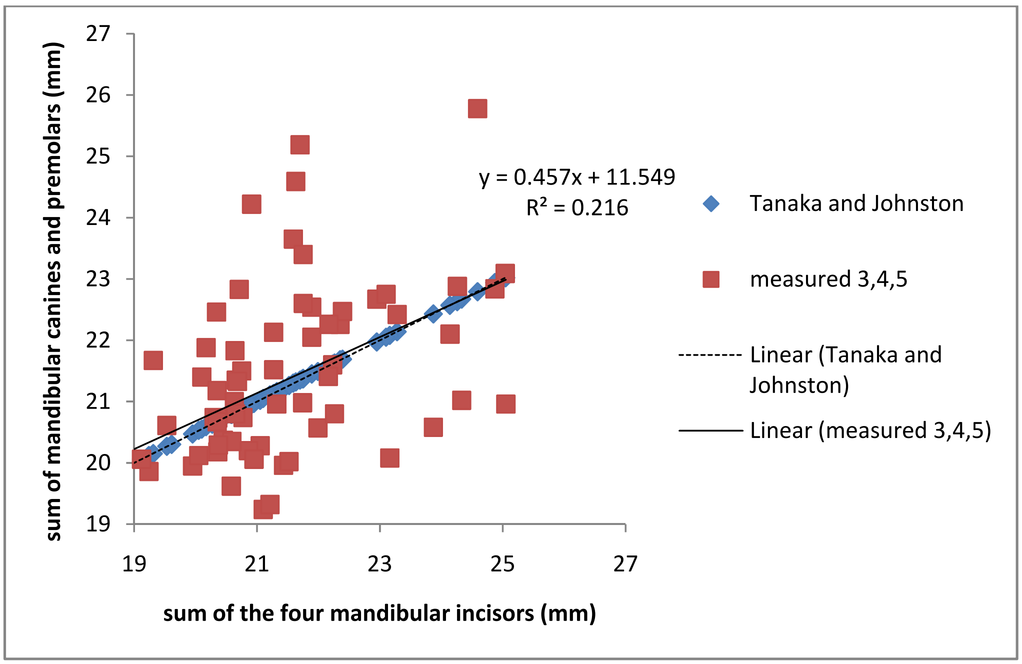

Figure 4.2: Graph illustrating comparison of sum of measured mesiodistal tooth-widths of mandibular canines and premolars with predicted values obtained using Tanaka and Johnston[1] equation

Figure 4.3 illustrates the graphic comparison between the sum of measured mesiodistal tooth-widths of the mandibular canines and premolars with predicted values obtained using the Melgaço et al[3] equation for the male sample. The Melgaço et al[3] equation overestimated the sum of mesiodistal tooth-widths of canines and premolars for sum of predictor teeth below 44mm and underestimated when the sum of predictor teeth was above 44mm.

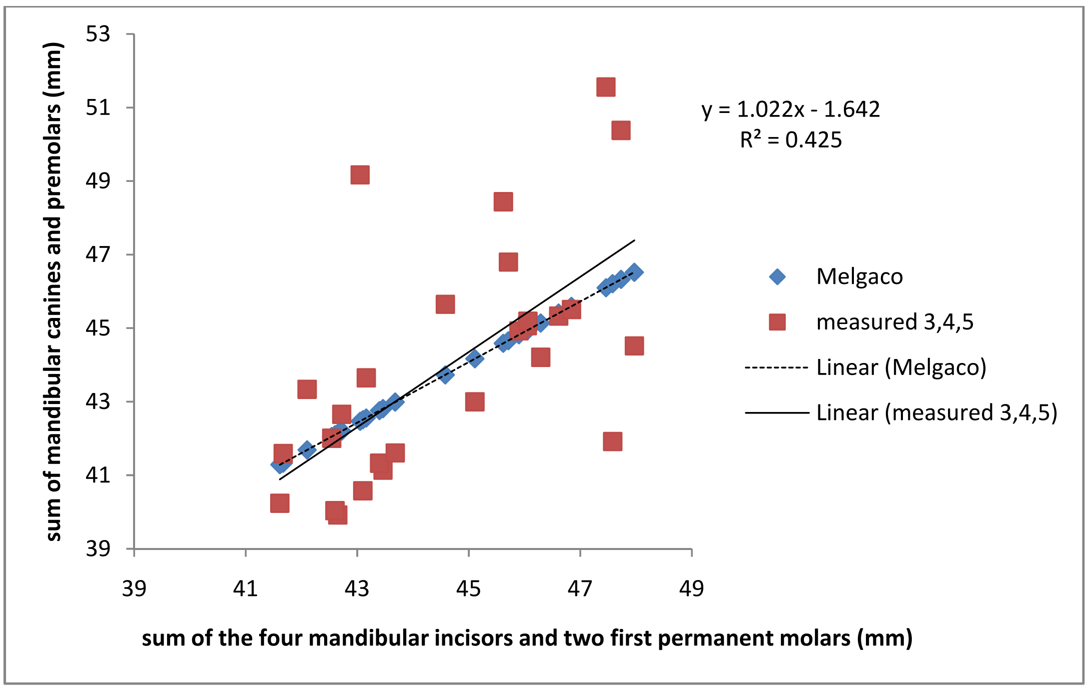

Figure 4.3: Graph illustrating comparison of sum of measured mesiodistal tooth-widths of mandibular canines and premolars with predicted values obtained using Melgaco et al[3] equation

Figure 4.4 illustrates the graphic comparison between the sum of measured mesiodistal tooth-widths of the mandibular canines and premolars with predicted values obtained using the Melgaço et al[3] equation for the female sample. The Melgaço et al[3] equation generally overestimated the sum of mesiodistal tooth-widths of canines and premolars in the female sample.

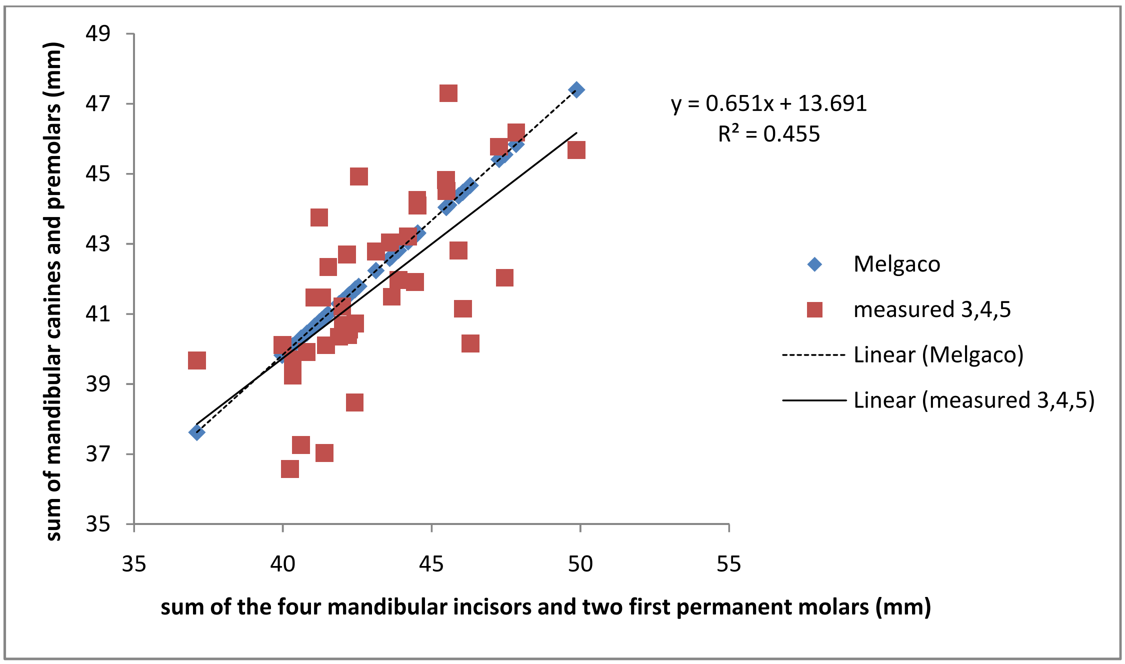

Figure 4.4: Graph illustrating comparison of sum of measured mesiodistal tooth-widths of mandibular canines and premolars with predicted values obtained using Melgaco et al[3] equation for the female sample

Figure 4.5 illustrates the graphic comparison between the sum of measured mesiodistal tooth-widths of the mandibular canines and premolars with predicted values obtained using the Melgaço et al[3] equation for the combined sample. The Melgaço et al[3] equation slightly overestimated the sum of mesiodistal tooth-widths of the canines and premolars but for sum of predictor teeth above 46mm, the measured and predicted values were almost equal.

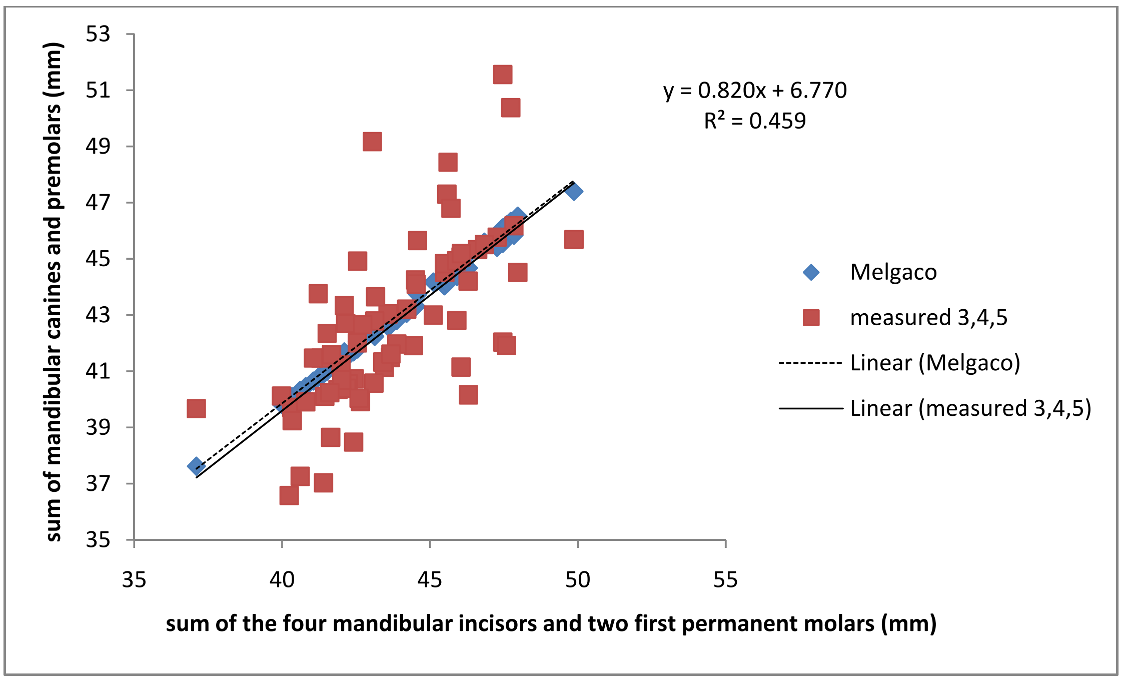

Figure 4.5: Graph illustrating comparison of sum of measured mesiodistal tooth-widths of mandibular canines and premolars with predicted values obtained using Melgaco et al[3] equation for the female sample

CHAPTER FIVE

5.0 DISCUSSION

5.1 Summary

This discussion will highlight the strength of the methodology used as well as the representativeness of the sample. The mesiodistal tooth-widths obtained from this sample will be compared with mesiodistal tooth-widths from other studies. Gender differences of the mesiodistal tooth-widths of the sample will also be explained. In addition, the actual (measured) values of the sum of mesiodistal tooth-widths of the permanent canine, first and second premolar compared to the predicted values will be compared and contrasted with findings from other studies. Finally the accuracy of the various prediction equation methods with reference to the actual (measured) values of the sum of mesiodistal tooth-widths of the permanent canine, first and second premolars will be explained.

5.2 Methodological considerations

Odontometric measurements specifically the measurements of mesiodistal tooth-widths were done to obtain data for the present study. The method by Hunter and Priest[32] in which the digital vernier calliper was placed perpendicular to the occlusal plane between the contact points was used. The Moorrees et al[17] method measures mesiodistal tooth-width with the digital vernier calliper parallel to the occlusal plane between the contact points. The Hunter and Priest[32] method was used because it was possible to measure mesiodistal tooth-widths of even slightly rotated teeth.

The sample for the present study was selected from 13-17 year old Kenyans of African descent who satisified the inclusion criteria. Maxillary and mandibular arch impressions were then made. Ngesa[6], Diagne et al[13] and Buwembo et al[24] also obtained their mesiodistal tooth-width data by taking impressions of the dental arches from individuals. However, other studies[3,4,5,14,31] have obtained their mesiodistal tooth-width data from study casts of individuals undergoing or having completed orthodontic treatment.

The digital vernier calliper was used because it enabled ease of obtaining the measurements without straining the eye or approximating if a conventional vernier calliper would have been used. Similar studies[3, 4, 5, 6] have used digital vernier callipers to obtain odontometric data.

The tests used for statistical analysis in the present study were consistent with other similar studies in which bilateral symmetry and gender differences were investigated. Data was first tested for normality and then descriptive statistics were calculated. The paired t test assessed bilateral symmetry of groups of teeth while the independent t test compared mesiodistal tooth-widths between the male and female samples.

Validity and reliability are used to describe the accuracy of the various prediction equations, be they single linear regression or multiple linear regression equations[20]. Luu et al[20] defined validity as the ability to truly measure what is intended to be measured. It can be determined from the mean differences between two measured values[20]. They also defined reliability as the consistency with which a measurement is made and it can be determined from measures of error and correlation of repeated mixed dentition analysis for the same patient[20].

Validity in the present study as determined by the mean differences ranged from 0.20 to 0.46 millimetres when the Melgaço et al[3] equation was used and from 0.01 to 1.03 millimetres when the Tanaka and Johnston[1] equation was used. These mean differences are within the 1 mm overestimation or underestimation allowed per quadrant when prediction equations are used[3, 5]. Therefore, the predicted values obtained in the present study can be considered as being valid. Reliability was determined by calculating the intraclass coefficient correlation between dental casts selected at random and measured twice in a week period, as proposed by Buwembo et al[24].

5.3 Representativeness of the sample

The choice of the two secondary schools was because they are national schools. National schools admit students from all counties of Kenya. Therefore, by sampling students from the schools it was assumed that the sample would represent reasonably well the Kenyan population.

The sample size was chosen by using the Kirkwood and Sterne[18] formula. The criteria used to select the sample size were adapted from a previous Kenyan study[6] that measured mesiodistal tooth-widths. These criteria were chosen because they were deemed to be sound and enabled comparison of the findings of the previous Kenyan study[6] with the present study.

5.4.0 Mesiodistal tooth-widths

The mean mesiodistal tooth-widths and coefficient of variation (CV) of individual tooth types were calculated (Tables 4.1 and 4.2) and compared to other studies (Table 4.3).

The CV in the present study is a measure of the variability of mesiodistal tooth-widths[16]. The higher the CV the higher the variability of a measurement and vice versa. In the present study as shown in Tables 4.1 and 4.2, the highest CV was observed for the second mandibular premolars and the lowest CV was observed for the first permanent mandibular molars. The low CV value of the first permanent mandibular molars justified its use in one of the prediction equations used in the present investigation. The four permanent mandibular incisors although commonly used as predictor teeth do not have the lowest CV values[16,27]. The present investigation also found CV values of the four permanent mandibular incisors not to be the lowest. Their continued use as predictor teeth is mainly due to their favourable position in the mandibular arch that facilitates ease of measurement[6].

A study[16] to compare mesiodistal tooth-widths and buccolingual crown dimensions of Nigerian and British children found the highest CV in the mandibular central incisors and the lowest CV in the first permanent mandibular molars among Nigerians. In the British sample, the highest CV was observed in the maxillary second premolars and the least CV in the maxillary permanent canines[16]. The study[16] reported that the variability in mesiodistal tooth-width maybe as a result of tooth type and location in the dental arch. The maxillary lateral incisors are the teeth that have the most varied shape and size. Therefore, in any odontometric study, the CV for the maxillary lateral incisors would be expected to be highest. However, in the present study and the study by Otuyemi and Noar[16] that was not the case. In the present study the mandibular second premolars had the highest CV and in the study by Otuyemi and Noar[16] the mandibular central incisors had the highest CV. This is because individuals with peg shaped maxillary lateral incisors do not fulfil the inclusion criteria for most odontometric studies and hence do not contribute to the CV calculation. However, in a study on Southern Chinese children, the CV was found to be highest for the maxillary lateral incisors despite the inclusion criteria stating that malformed teeth were not included in the study[27]. A 'malformed' tooth was not defined in that study.

Garn et al[61] reported that tooth size is genetically controlled and that environmental factors have little effect on tooth size. They further reported that variation in tooth size between quadrants of the same dental arch is controlled by local genetic factors and that the more distally positioned teeth have greater variation in tooth size. In the present investigation the first permanent mandibular molar showed the least variability.

5.4.1 Bilateral symmetry in mesiodistal tooth-widths

Similarity of teeth between the left and right sides of a dental arch is assumed[6]. This enables mesiodistal tooth-width measurements of one quadrant to be used to represent the other side of the quadrant specifically in a clinical setting[6]. Mixed dentition space analysis uses measurements from one quadrant in estimating the total tooth material for a dental arch[1].

In the present investigation, statistically significant bilateral differences were found in males for mandibular first permanent molars and maxillary second premolars. In females, statistically significant bilateral differences were found in the maxillary first permanent molar and mandibular first and second premolars. The whole sample showed statistically significant bilateral differences for the mandibular second premolar and maxillary first permanent molar. The absolute mean differences between antimeric teeth ranged from 0.12 to 0.17mm. These differences are small and not clinically significant. Mean mesiodistal tooth-widths of the antimeres were thus used in calculations in the prediction equations.

A previous Kenyan study[6] found statistically significant differences for mandibular lateral incisors, maxillary canines and first premolars. However, in this Kenyan study the p value was adjusted using the Bonferroni correction and no statisitically significant differences were then observed. A Brazilian study[3] showed no statistically significant differences between the left and right sides for mesiodistal tooth-widths of all contralateral teeth. A Jordanian study[28], found statistically significant differences for the maxillary and mandibular second premolars. Bishara et al[25] in their study on North American, Mexican and Egyptian samples found statistically significant differences for 9 antimeres. However, they did not specify the individual teeth or the samples from which the teeth were derived. The differences between antimeres in their study ranged from 0 to 0.24mm which they considered small and not clinically significant.

5.4.2 Gender differences in mesiodistal tooth-widths

Mesiodistal tooth-widths of individual teeth for male participants were generally larger than for female participants as shown in Tables 4.11 and 4.12. However, there were only statistically significant differences in the mandibular permanent canines and first permanent molars, maxillary lateral incisors and permanent canines. For the sum of the four incisors, there was no statistically significant difference in the mandibular arch between male and female participants (Table 4.13). The sum of the four incisors in the maxillary arch showed a statistically significant difference between male and female participants (Table 4.13). There were statistically significant differences in both the mandibular and maxillary arches for the sum of the mesiodistal tooth-widths of the permanent canines and premolars between male and female participants (Table 4.14). These significant differences justified the use of two (male and female) separate regression equations including the first permanent molars as predictor teeth.

The mean differences for the individual mandibular teeth with statistically significant differences were 0.55mm for the canine and 0.47mm for the first permanent molar. Mean differences for individual maxillary teeth with statistically significant differences were 0.30mm for the lateral incisor and 0.55mm for the canine. For the sum of incisors the mean difference was 1.15mm in the maxillary arch and for the sum of mesiodistal tooth-widths of permanent canine and premolars the mean differences were 1.04mm for the mandibular and 1.07mm for the maxillary arch. Clinically significant differences (more than 1mm mean difference per quadrant) were found in the sum of incisors for the maxillary arch while the sum of mesiodistal tooth-widths of permanent canine and premolars in both the mandibular and maxillary arches was just within the accepted limit.

Several studies of African populations have also found that the sum of mesiodistal tooth-widths of the canines and premolars is larger in males than females[6,13,14,24]. Studies on Mongoloid populations have also reported that there are significant differences in mesiodistal tooth-widths of groups of teeth between male and female subjects[26,31]. These findings were not any different in Caucasian populations[3].

A previous Kenyan study[6] reported larger mesiodistal tooth-widths in males than in females for both dental arches. It also showed statistically significant differences in all teeth except the mandibular second premolars. In this Kenyan study[6] when groups of teeth were compared, it was found that males had significantly larger sum of mesiodistal tooth-widths of canines and premolars than females. A Ugandan study[24] also found that the combined sum of mesiodistal tooth-widths of mandibular and maxillary canines and premolars was significantly larger in males than females.

Diagne et[13] in a Senegalese population found that the canine-premolar segments in both the mandibular and maxillary arches were significantly larger in males than females. An Indian study[31] as well showed that the sum of mandibular incisors and sum of mandibular and maxillary canines and premolars was significantly larger in males than females. Jaroontham and Godfrey[26] in a Thai population also found that the mandibular incisors and sum of mandibular and maxillary canines and premolars to be significantly larger in males than females. A Southern Chinese population study[27] revealed larger absolute mesiodistal tooth-widths in both dental arches in males than females for all tooth types. The study also reported that all teeth except the mandibular lateral incisors had statistically significant differences. Al-Bitar et al[28] in their study on a Jordanian population found that males had significantly greater sum of mandibular incisors than females, the canine-premolar segments were also significantly greater in males than females and that all teeth had statistically significant differences except for the mandibular right central incisors and the maxillary right and left second premolars.

In a study[3] on White Brazilian children, it was found that males had wider teeth than females and that the differences were statistically significant[3]. However, this Brazilian study did not categorize the teeth into individual tooth-type or groups of teeth. Bishara et al[25] in their study comparing mesiodistal tooth-widths in three different populations, reported that in their Egyptian sample, males had significantly larger maxillary and mandibular canines than females as well as significantly larger sum of mesiodistal tooth-widths of maxillary permanent canines and premolars. The Mexican sample in the same study showed that both mandibular and maxillary canines, first and second premolars and first permanent molars were significantly larger in males than females. In the American sample of the same study, both mandibular and maxillary permanent canines and first molars were significantly larger in the males than the females. In concurrence with previous studies the present findings indicate that males have larger mesiodistal tooth-widths than females. Also, like the previous studies[3, 13, 25, 27], statistically significant differences were not found in all measured permanent teeth between males and females. However, since different studies set the p value at different levels, comparison of the different studies should be done cautiously. The present study is consistent with the findings of other authors[3,6,24,25,27,28,31] that there is a gender difference in the mesiodistal tooth-widths between males and females.

5.4.3 Population differences in mesiodistal tooth-widths

Several authors have reported racial and ethnic differences in mesiodistal tooth-widths[3, 5, 6, 13, 14]. The mean mesiodistal tooth-widths of individual tooth-types in the present study were compared with other studies from a Southern Chinese[27] and North American[17] sample. Overall the North American sample had smaller mean mesiodistal tooth-widths for both genders than the present study (Table 4.3). However, the mandibular and maxillary incisors for both genders and canine in females had larger mean mesiodistal tooth-widths than in the present study. The Southern Chinese had larger mean mesiodistal tooth-widths than those of the present study for both males and females.

The mean values of mesiodistal tooth-widths of the different groups of teeth in the present study were different from those of other studies (Table 4.4). The Indian study[31] had the largest mean mesiodistal tooth-widths for the mandibular incisors and maxillary canine and premolars while the Black South African study[14] had the largest mean mesiodistal tooth-widths for mandibular canine and premolars.

These findings demonstrate differences in mesiodistal tooth-widths in different racial groups. Due to these racial differences and in concurrence with other authors[3,5,6,13,14], the Tanaka and Johnston[1] equation was found not to be applicable for the mandibular arch in the combined sample (males and females). The Tanaka and Johnston[1] equation has thus been modified by several authors[5, 24]. Their modifications were found to be more accurate in predicting the sum of mesiodistal tooth-widths of the permanent canines and premolars in their populations. Similarly, new prediction equations for this Kenyan sample were formulated (see section 5.8.2).

5.5 Comparison of prediction equations values with actual (measured) values

Prediction equation values are derived from prediction equations. While actual (measured) values are directly measured from the dental casts. Prediction equations are either single linear regression equations (SLRE) or multiple linear regression equations (MLRE) [20]. MLRE provide higher correlation coefficients and better accuracy because of the use of more variables, but they are complex and difficult to memorize[3]. The SLRE are commonly used because they are non-radiographic, simple and practical for the dentist to use[3, 4].

Nourallah et al[5] stated that for a predictive method to form part of contemporary orthodontic practice, it must be accurate, safe and simple to use. The Tanaka and Johnson[1] equation is one such predictive method that fits the above criteria. However, its main shortcoming is that it is not applicable in non-Caucasian populations without modification[3,5,6]. The sum of the four permanent mandibular incisors is widely used as a predictor in single linear regression equations mainly due to ease of measurement of these teeth both in the mouth and on dental casts[6]. They however do not have the least variability as measured by the coefficient of variation (CV)[16,27]. They are mainly used due to their location in the mandibular arch[6]. Addition of other teeth to the permanent mandibular incisors has been shown to increase the value of the correlation coefficient[3,4,5]. Mandibular first permanent molars were added to the mandibular incisors and used as predictors in a Brazilian study[3]. Maxillary first permanent molars were also added to the mandibular incisors and used as predictors in a Syrian population[5]. An Indian study added the mandibular first permanent molars to the mandibular incisors to predict the sum of mesiodistal tooth-widths of the mandibular canines and premolars[4]. In the same study[4], the maxillary first permanent molars were added to the mandibular incisors to predict the sum of mesiodistal tooth-widths of the maxillary canines and premolars. However, addition of some other teeth to the mandibular permanent incisors is not always possible as some teeth may delay in erupting, have abnormal morphology or be covered distally by gingiva[5, 6]. The present study added the mandibular first permanent molars to the permanent mandibular incisors to predict the sum of the mesiodistal tooth-widths of the mandibular permanent canine and premolars for both sides of the arch. This was informed by the high correlation coefficient of 0.810 that was obtained in a Brazilian study[3] that did not use radiographs. This correlation coefficient is similar to that obtained from a study[8] that used radiographs to predict the mesiodistal tooth-widths of unerupted canines and premolars. The present study compared the actual (measured) mesiodistal tooth-widths and the predicted values obtained using the Tanaka and Johnston[1] and Melgaço et al[3] equations.

The Tanaka and Johnston[1] equation does not have separate equations for males and females; however it has separate equations for the maxillary and the mandibular arches. In the present investigation, the Tanaka and Johnston[1] equation underestimated the sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars, while in the maxillary arch it overestimated the sum of mesiodistal tooth-widths of the permanent canines and premolars as shown in Table 4.15. However, the differences were not statistically significant. A previous Kenyan study[6] found that the Tanaka and Johnston[1] equation overestimated the sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars, while it underestimated the sum of mesiodistal tooth-widths of the maxillary permanent canines and premolars. The mean differences reported in this previous Kenyan study were not statistically significant. In a Ugandan study[24], the Tanaka and Johnston[1] equation underestimated the sum of the mesiodistal tooth-widths of the mandibular permanent canine and premolars and overestimated the maxillary permanent canines and premolars. The mean differences for this Ugandan study were also not statistically significant. The present study conforms to other studies in which the Tanaka and Johnston[1] equation either overestimates or underestimates the sum of mesiodistal tooth-widths of the permanent canines and premolars. Also, that the mean differences were found not to be statistically significant. The absolute mean differences for the present study ranged from 0.09 to 0.11mm, the previous Kenyan study[6] 0.075 to 0.078mm and the Ugandan study[24] ranged from 0.70 to 0.75mm. These absolute mean differences are not clinically significant. This is because a discrepancy of less than 1mm in the sum of canine and premolars in one quadrant has been shown not to influence extraction or non-extraction treatment choice[3, 25].

Melgaço et al[3] developed a regression equation for only the mandibular arch because arch length is more diminished in the mandible compared to the maxilla especially during the transition from primary to permanent dentition[3]. Separate equations were developed for males and females because gender differences in the mesiodistal tooth widths have been reported[3, 5, 6, 13, 14]. The present study adopted the Melgaço et al[3] equation because it is a non-radiographic prediction method, it is simple and easy to use and it has a high correlation coefficient comparable to correlation coefficients obtained from radiographic prediction methods. In the present study, using the Melgaço et al[3] equation, the absolute mean differences between the measured values of sum of mesiodistal tooth-widths of mandibular permanent canines and premolars and predicted values ranged from 0.18 to 0.46mm, with males 0.18 ± 2.51mm, females 0.46 ± 1.88mm and the combined sample 0.20 ± 2.17mm as shown in Table 3.14. Melgaço et al[3] reported smaller absolute differences ranging from 0 to 0.02 mm with males 0.02 ± 1.49mm, females 0.04 ± 1.36mm and the combined sample 0.00 ± 1.44mm. There were no statistically significant differences between the predicted values of the sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars obtained using the Melgaço et al[3] equations and the actual (measured) values for either males, females or the combined sample (Table 4.16). Therefore, the present findings indicate that the Melgaço et al[3] equation can be used to predict better the sum of mesiodistal tooth-widths of the mandibular permanent canine and premolars for both males and females than the Tanaka and Johnston[1] equation. The correlation coefficients obtained when using the Tanaka and Johnston[1] equation for the mandibular arch were lower than for the Melgaço et al[3] equation in the combined sample.

5.6 Accuracy of prediction equations

Correlation coefficients (r) were used to evaluate relationships between the predictor teeth and the estimated value obtained using a prediction equation[13]. The Pearson correlation coefficient was used to compare prediction equations because it is independent of both scale of measurement and sample size[6]. A correlation coefficient of one (1) would mean a perfect relationship between the predictors and the calculated value from the prediction equation. Studies to predict the sum of mesiodistal tooth-widths of permanent canines and premolars using the radiographic methods have reported high correlation coefficients of 0.870 to 0.950, while those using single linear regression equations only have reported moderate to high correlation coefficients of 0.720 to 0.990[20]. An r value of 0.6 is considered clinically significant[6, 20]. Luu et al[20] do not recommend use of a prediction equation with an r value of less than 0.6. The r values for the present study are shown in Table 4.18.

Comparison of r values obtained in the present study and r values from other studies is shown in Table 4.18. In the mandibular arch when the four permanent mandibular incisors were used as predictor teeth, the r values for both genders and combined sample were lower than in the other studies[1,3,13,24,28,30,31]. In the maxillary arch when the four permanent mandibular incisors were used as predictor teeth, the r values for males and combined samples were lower than in the other studies. However, for the females, the r value was higher than the Senegalese[13] and Jordanian[28] studies. When the four permanent mandibular incisors and two first permanent molars were used as predictor teeth similar to the Melgaço et al[3] study, the r values obtained in the present study for the mandibular arch were lower than in the Melgaço et al[3] study. When the r values obtained using the four permanent mandibular incisors and two first permanent molars as predictor teeth were compared with the four permanent mandibular incisors as predictor teeth, in males for the mandibular arch, the r value was generally lower than in other studies except for the Jordanian[28] study where it was similar. For the maxillary arch, the r value was higher than the

Senegalese[13], Jordanian[28] and Indian[31] studies but lower than the Ugandan[24] study. In females for the mandibular arch, the r value was similar to the Indian[31] study, higher than the Senegalese[13] study and lower than the other studies[3,28,30]. For the maxillary arch, the r value was higher than for all the other studies except the Ugandan[24] study. In the combined sample for the mandibular arch, the r value was higher than the Tanaka and Johnston[1] and Jordanian[28] studies but lower than the Brazilian[3], Senegalese[13] and Ugandan[24] studies. For the maxillary arch, the r value was only lower than the Ugandan[24] study.

The only correlation coefficients that are clinically significant[20] when using the four permanent mandibular incisors in the present study are for maxillary arch in females and in the combined sample with r values of 0.630 and 0.605 respectively (Table 4.18). The low correlation coefficients in the present study between the sum of the four permanent mandibular incisors and the sum of mesiodistal tooth-widths of the mandibular permanent canine and premolars in the male and combined samples precluded the formulation of single linear regression equations for the present Kenyan sample. However, Diagne et al[13] obtained correlation coefficients mostly above 0.6 except for the female maxillary arch and thus single linear regression equations were formulated for their study. The Buwembo et al[24] and Diagne et al[13] studies found that the Tanaka and Johnston[1] equation overestimated the mesiodistal tooth-widths of the permanent canines and premolars and therefore recommended the use of prediction equations that they had formulated for their respective populations.

When the four permanent mandibular incisors and first permanent molars were used to predict the sum of mesiodistal tooth-widths of the mandibular permanent canines and premolars in the present investigation, the r values obtained were; 0.652 for the males, 0.674 for females and 0.678 for the combined sample (Table 4.18). The r values are moderate (above 0.6) and thus can be considered clinically significant[6, 20]. The Melgaço et al[3] study obtained r values of 0.795 for males, 0.774 for females and 0.810 for the combined sample (Table 4.18). These are high correlation coefficients and the r value for the combined sample from the Melgaço et al[3] study compares favourably well with the correlation coefficients obtained from radiographic prediction methods which are considered most accurate[3,4,8]. The correlation coefficients from the present investigation using the predictor teeth proposed by Melgaço et al[3] although not as high as those from the original Melgaço et al[3] study can still be considered clinically useful and this equation can be used in the Kenyan population.

The difference in correlation coefficients obtained despite the same predictor teeth being used could be as a result of differences in mesiodistal tooth-widths in different racial and ethnic groups[3, 4, 5, 6]. The present study was carried out on Kenyans of African descent while the Melgaço et al[3] equation was carried out on White Brazilians.

5.7 Comparison of prediction equations in space analysis

Two single linear regression equations were investigated in the present study. The Tanaka and Johnston[1] equation is a commonly used prediction equation due to its simplicity and being practical in use[6]. However, it has to be modified to be used in different racial and ethnic groups since it was derived from a Caucasian sample[5,6,24]. It has been shown to overestimate the sum of mesiodistal tooth-widths of the permanent canines and premolars in several studies of African populations[13, 24]. The Melgaço et al[3] equation was developed after observing that using only the four permanent mandibular incisors to predict the sum of mesiodistal tooth-widths of the permanent canines and premolars gave low correlation coefficients (r). The r value obtained using the Melgaço et al[3] equation was 0.810 for both males and females which is high and similar to r values obtained by use of radiographic prediction methods[3]. It is also simple and practical to use.

The r values obtained using the four permanent mandibular incisors in the present study were 0.465 for the mandible and 0.605 for the maxilla (Table 4.18). The r values obtained using the four permanent mandibular incisors and first permanent molars in the present study were 0.652 for the males and 0.674 for the females and 0.678 for the combined sample in the mandibular arch (Table 4.18). Those values were lower than the original Melgaço et al[3] study of 0.795 for males, 0.774 for females and 0.810 for the combined sample. In the maxillary arch, the r values obtained were; 0.725 for males, 0.718 for females and 0.741 for the combined sample (Table 4.18). These correlation coefficients are higher than for the mandibular arch. The Melga□o et al[3] equation can therefore predict better the sum of mesiodistal tooth-widths of the maxillary permanent canine and premolars than the mandibular permanent canine and premolars. However, it was developed for use in the mandibular arch since arch perimeter is diminished during the transition from mixed to permanent dentition more in the mandibular than the maxillary arch[3].

Comparison of different r values obtained from different studies is shown in Table 4.18. Most studies have moderate to high r values including the present study. Only the study by Buwembo et al[24] has similar r values to the Melgaço et al[3]. These r values are considered high because they approximate those values obtained using radiographic prediction methods which could be considered ‘gold standard’.

The absolute mean differences between actual (measured) values and values obtained using the Tanaka and Johnston[1] equation were; 0.11mm and 0.09mm for the mandibular and maxillary arches respectively (Table 4.15). These differences were not statistically significant at p-value (p≤ 0.05) of 0.47 and 0.49 for the mandibular and maxillary arches respectively. While the absolute mean differences between actual (measured) values and values obtained using the Melgaço et al[3] equation were, 0.18mm for males, 0.20mm for females and 0.46mm for the combined sample which were not statistically significant at p-value (p≤ 0.05) of 0.45 (Table 4.16). Comparison of the predicted sum of mesiodistal tooth-widths of the permanent mandibular canine and premolars using both the Tanaka and Johnston[1] equation and Melgaço et al[3] equations (Table 4.17), revealed an absolute mean difference of 0.43mm. This was statistically significant at p-value (p≤ 0.05) of 0.00.

Previous studies[21,25] have stated that absolute mean differences between measured values and values obtained using prediction equations for the sum of mesiodistal tooth-widths of permanent canines and premolars of less than 1mm not to be clinically significant. This difference is spread across three teeth; canine, first and second premolars. It therefore does not affect an extraction or non-extraction decision during the mixed dentition period[3,25]. In the present investigation, absolute mean differences obtained using both the Tanaka and Johnston[1] and Melgaço et al[3] equations were all less than 1mm and can therefore be considered to be not clinically significant.

5.8 CONCLUSIONS AND RECOMMENDATIONS

5.8.1 Conclusions

1. This study has provided additional data on individual tooth-type mesiodistal tooth-width dimensions for Kenyans.
2. Inclusion of the mandibular first permanent molars to the four permanent mandibular incisors gave higher correlation coefficients.
3. The Melgaço et al[3] equation better predicted the sum of the mesiodistal tooth-widths of the mandibular permanent canine and premolars than the Tanaka and Johnston[1] equation.

5.8.2 Recommendations

Males have larger mesiodistal tooth-widths than females, therefore space analysis should be done separately for each gender.

There was bilateral symmetry of the different groups of teeth within the arch. Thus, teeth on one side can be used to estimate mesiodistal tooth-widths of contra-lateral teeth.

Space analysis should be ethnic group/population specific because of the difference in mesiodistal tooth-widths among populations.

Clinicians and researchers may use the following equations formulated using data from the present investigation to predict the sum of mesiodistal tooth-widths of mandibular permanent canines and premolars:

$y = 1.022x - 1.638$ for males

$y = 0.651x + 13.705$ for females

$y = 0.821x + 6.762$ for males and females

Where:

y is predicted sum of mesiodistal tooth-widths of mandibular permanent canine and premolars in both quadrants

x is the sum of the mesiodistal tooth-widths of the four mandibular permanent incisors and two first molars

Additional research needs to be done in other ethnic and regional groups to test the Melgaço et al[3] equation, applicability of the Tanaka and Johnston[1] equation and to obtain more data on mesiodistal tooth-widths of the Kenyan population.

5.9 Limitations

This was a school based study with a limited number of participants. A larger sample size from the general population should be studied to obtain more representative data of mesiodistal tooth-widths of the Kenyan population, test the Melgaço et al[3] equation and applicability of the Tanaka and Johnston[1] equation.

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56. ***Arslan SG, Dildes N, Kama JD, Genç Celal.*** Mixed-dentition analysis in a Turkish population. *World J Orthod* 2009; 10: 135-140.

57. ***Al-Dabagh DJ.*** Prediction of mesio-distal width of maxillary canines depending on mesio-distal width of mandibular canines by using regression equations. *J Bagh College Dentistry* 2011; 23: 114-118.

58. ***Legovic A, Maricic BM, Skrinjaric A, Butorac MZ, Mestrovic S, Varga LN.*** Importance of interincisal index for predicting mesiodistal crown diameters of canines and premolars. *Coll Anthropol* 2012; 4: 1287-1291.

59. ***Alvaran N, Roldan SI, Buschang PH.*** Maxillary and mandibular arch widths in Colombians. *Am J Orthod Dentofacial Orthop* 2009; 135: 649-656.

60. ***Garn SM, Lewis AB, Kerewsky RS.*** The meaning of bilateral asymmetry in the permanent dentition. *J Dent Res* 1966; 36: 55-62.

APPENDICES

Appendix I: Approval letter from the ethics and research committee of the 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
12th August 2011

Ref: KNH-ERC/ A/207

Dr. Nduguyu Kerre
Dept.of Paediatric Dentisty and orthodontics
School of Dental Sciences
University of Nairobi

Dear Dr. Kerre

RESEARCH PROPOSAL: " MESIODISTAL TOOTH WIDTHS OF PERMANENT TEETH IN 13-15 YEAR OLD KENYAN" (P252/6/2011)

This is to inform you that the KNH/UON-Ethics & Research Committee has reviewed and **approved** your above revised research proposal . The approval periods are 12th August 2011 11th August 2012.

You will be required to request for a renewal of the approval if you intend to continue with the study beyond the deadline given. Clearance for export of biological specimens must also be obtained from KNH/UON-Ethics & Research Committee for each batch.

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

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

Yours sincerely

Aguantai

PROF A N GUANTAI
SECRETARY, KNH/UON-ERC

c.c. The Deputy Director CS, KNH
The Dean, School of Dental Sciences, UON
The HOD, Records, KNH
Supervisors: Dr. P.M. Ng'ang'a, Dept.of Paediatric Dentistry and Orthodontics,UON
Dr. J. L. Ngesa,Dept.of Paediatric Dentistry and Orthodontics, UON
Dr. G.P. Pokhariyal, School of Mathematics, UON

Appendix II: Approval letter from the Ministry of Education

MINISTRY OF EDUCATION

Telegrams: "SCHOOLING", Nairobi
Tel. 0202453699 Fax 2244831 Nairobi

When replying please quote

PROVINCIAL DIRECTOR OF EDUCATION
NAIROBI PROVINCE
NYAYO HOUSE

P.O.BOX 74629- 00200
NAIROBI

Ref: NP/GA/17/13

Date: 24TH AUGUST 2011

RE: TO WHOM IT MAY CONCERN; DR. NDUGUYU KERRE

This is to confirm that the above named is a student at the University of Nairobi pursuing a Masters Degree in Pediatric Dentistry and Orthodontics.
He is currently undertaking research as per the requirements of the university.

Any assistance given to him will be appreciated.

Thank you.

SAMUEL BOTO
FOR PROVINCIAL DIRECTOR OF EDUCATION
NAIROBI

Appendix III: Approval letter from Starehe Boys' Centre

Nduguyu Kerre
P.O Box 12782-00400
Nairobi.
19-September-2011.

The Director,
Starehe Boys' Centre and School,
P.O Box 30178-00100,
Nairobi.

Dear Sir,

RE: REQUEST FOR PERMISSION TO CARRY OUT ACADEMIC RESEARCH

I am a dentist currently pursuing a master's degree course in paediatric dentistry at the University of Nairobi Dental School. Carrying out research and writing a thesis is part of the course requirements. I chose Starehe to be one of my research sites.
I wish to examine 50 boys who are 13-15 years old.
I intend to examine the boys in the month of October, preferably on Saturday afternoons.

I am an old boy, file number 9980. I left in 1999, having been in S1, Horsten and POS houses. Choosing Starehe was therefore a natural choice because it is 'coming back home' and also because there's a dental clinic where I can examine the boys.

This is therefore a request for permission to conduct my research in Starehe.

Thank you.

Yours sincerely,

Nduguyu.K

Nduguyu Kerre

Approved.
22/9/2011

Attach to Dr Kar
You will work under Dr Karani.

DIRECTOR
STAREHE BOYS' CENTRE
P. O. Box 30178
NAIROBI, GPO - 00100.
TEL: 6761221-4

cc.. Dr. Karani
Dental Unit
Starehe Clinic.

Appendix IV: Approval letter from Starehe Girls'Centre

STAREHE GIRLS' CENTRE

A charitable Institution, Incorporating a National High School and Skills Training programme for girls.

P.O. Box 6847-00200,
Nairobi,
Kenya.

Tel: 254-020-2025500/1/2/3/4
Mob.: 0720-957454
e-mail: info@starehegirlscentre.co.ke

21st May, 2013.

<u>To Whom It May Concern</u>

Dear Sir/Madam,

<u>REF: DOCTOR NDUGUYU KERRE (DENTIST).</u>

This is to confirm that Dr. Nduguyu Kerre did a research on Dental Wellness in children ranging between the ages of 13 to 17 years. He was with us for 30 days. That is from 19th September to 20th October, 2011. He dealt with a total number of 4o girls.

For us it was a God sent chance, since we normally deal with children from disadvantage families allover the country and dental problems is a major challenge on the side of health issues.

We wish him all the best in his studies.

<u>"Elimu Yetu, Nguvu Yetu!"</u>

Yours faithfully,

AMangethe

Mrs. Agnes Kang'ethe
<u>Deputy Director/Academic Affairs.</u>

Appendix V: Consent Form

I am a postgraduate student pursuing a Master's Degree in Paediatric Dentistry and Orthodontics at the University Of Nairobi School Of Dental Sciences. I wish to conduct a study on ***'Prediction of mesiodistal widths of unerupted canines and premolars using a regression equation.'***

Perceived benefits/risks

There are no anticipated risks for participating in the study. In case of any pertinent findings, the participants will be given advice regarding the prevailing oral health condition and referred for relevant management. The information obtained from the study will be useful to general dentists and orthodontists. The study will also serve as a partial fulfilment for a Masters Degree in Paediatric Dentistry and Orthodontics.

I.. consent to take part in this study as explained to me by the principal investigator. I understand that all information given by me and the clinical finding obtained shall be held and treated with confidentiality and shall be used solely for the purpose of the purpose of the research.

Signature of the
participant...Date...

Signature of the
investigator..Date...

Appendix VI: Data capturing form

Serial number..

Patient's age
(years)..

Gender male female

Mesiodistal tooth-widths of the maxillary teeth (mm)

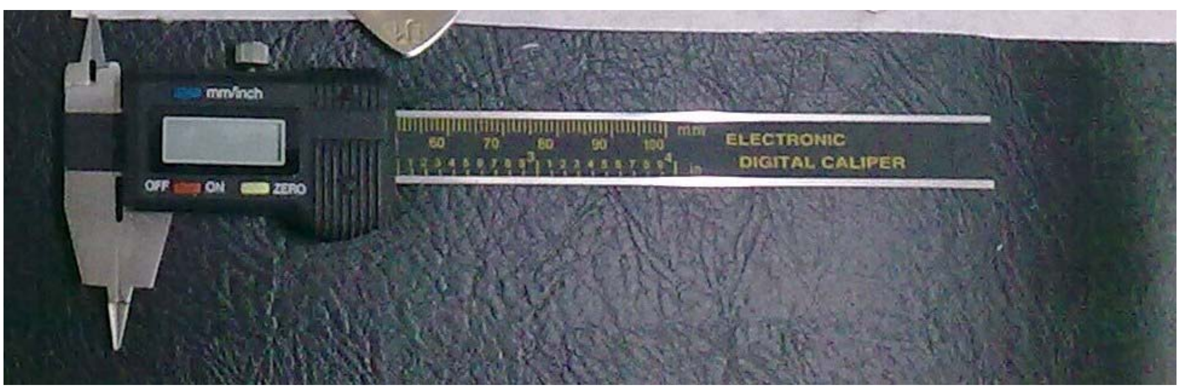
Tooth number	***16***	***15***	***14***	***13***	***12***	***11***	***21***	***22***	***23***	***24***	***25***	***26***
1st value(mm)												
2nd value(mm)												
Average value												

Mesiodistal tooth-widths of mandibular teeth (mm)

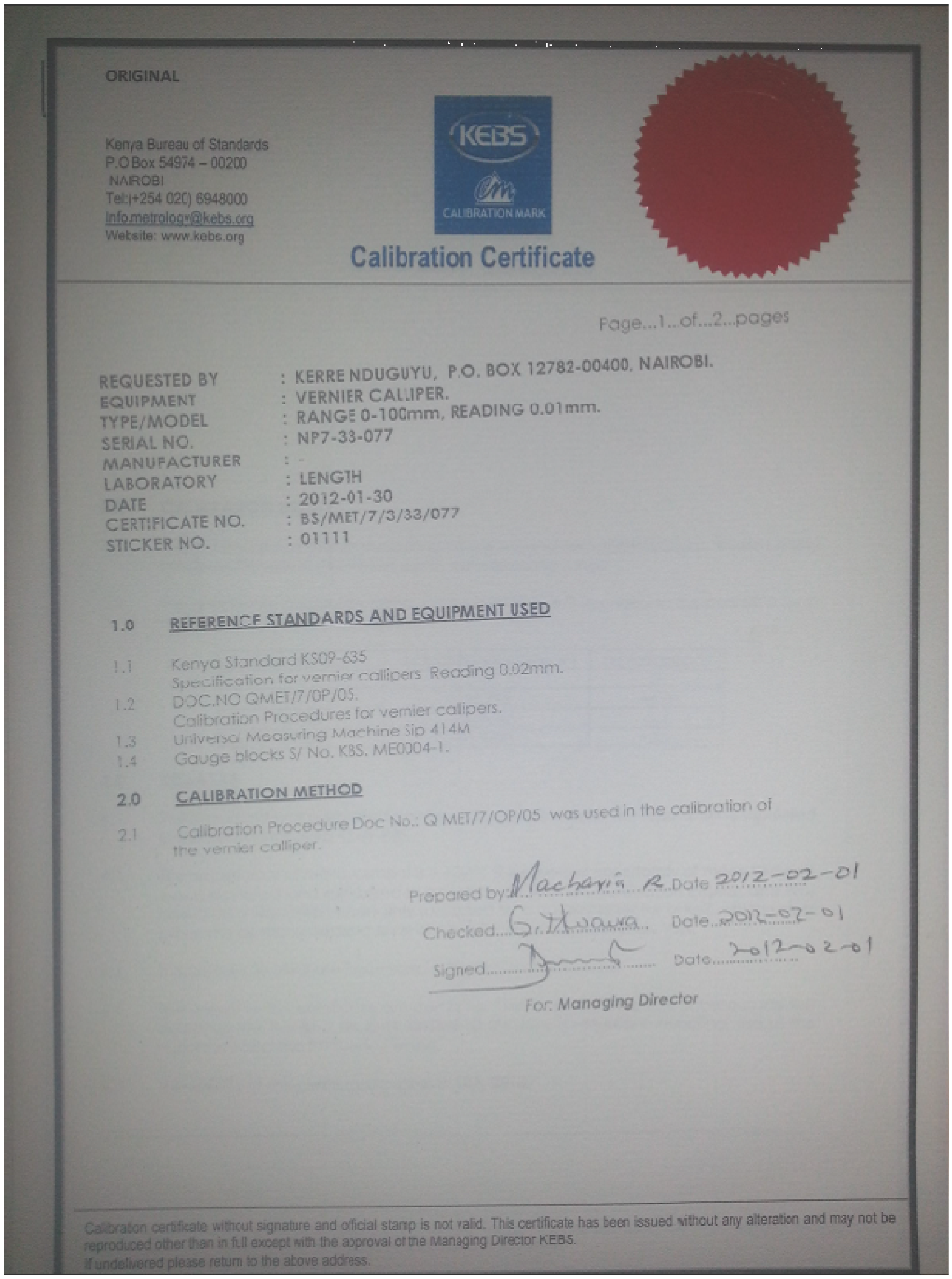
Tooth number	***36***	***35***	***34***	***33***	***32***	***31***	***41***	***42***	***43***	***44***	***45***	***46***
1st value(mm)												
2nd value(mm)												
Average value												

Appendix VII: Data collection instruments

Appendix VIII: Digital vernier calliper



Appendix IX: Calibration certificate for digital vernier calliper



ORIGINAL

Kenya Bureau of Standards
P.O Box 54974 – 00200
NAIROBI
Tel:(+254 020) 6948000
info.metrology@kebs.org
Website: www.kebs.org

KEBS
CALIBRATION MARK

Calibration Certificate

Page...1...of...2...pages

REQUESTED BY	: KERRE NDUGUYU, P.O. BOX 12782-00400, NAIROBI.
EQUIPMENT	: VERNIER CALLIPER.
TYPE/MODEL	: RANGE 0-100mm, READING 0.01mm.
SERIAL NO.	: NP7-33-077
MANUFACTURER	: -
LABORATORY	: LENGTH
DATE	: 2012-01-30
CERTIFICATE NO.	: BS/MET/7/3/33/077
STICKER NO.	: 01111

1.0 **REFERENCE STANDARDS AND EQUIPMENT USED**

1.1 Kenya Standard KS09-635
Specification for vernier callipers Reading 0.02mm.

1.2 DOC.NO QMET/7/0P/05.
Calibration Procedures for vernier callipers.

1.3 Universal Measuring Machine Sip 414M

1.4 Gauge blocks S/ No. KBS. ME0004-1.

2.0 **CALIBRATION METHOD**

2.1 Calibration Procedure Doc No.: Q MET/7/OP/05 was used in the calibration of the vernier calliper.

Prepared by: Macharia R. Date 2012-02-01

Checked... G. Thuawa... Date 2012-02-01

Signed.............. Date 2012-02-01

For: Managing Director

Calibration certificate without signature and official stamp is not valid. This certificate has been issued without any alteration and may not be reproduced other than in full except with the approval of the Managing Director KEBS.
If undelivered please return to the above address.

COPY

Kenya Bureau of Standards
P.C Box 54974–00200
NAIROBI
Tel:(+254 020) 6948000
info.metrology@kebs.org
Website: www.kebs.org

BS/MET/7/3/33/077

Calibration Certificate

3.0 CALIBRATION RESULTS

3.1 The maximum permissible measuring error **e** is found from $\pm(20+0.05L)\mu m$, where L is any measured length in millimetres within the measuring range.

3.2 The permissible parallelism tolerance is found from **e**/3 (rounded to the nearest $0.5\mu m$) where **e** is as defined in 3.1 above.

Calliper setting	Actual Reading(mean)	Deviation(μm)
0	0	0
27.79	27.796	+6.0
57.06	57.0546	-5.4
81.54	81.5421	+2.1

4.0 REMARKS

4.1 The instrument was calibrated and found to satisfy the accuracy requirements stipulated in the Kenya Standard KS 09-635.

4.2 The uncertainty of measurement is $\pm 13\mu m$, the reported uncertainty of measurements was calcuated and expressed in accordance with EAL publication EAL-R2. and was based on a standard uncertainty multiplied by a coverage factor of k=2, which unless otherwise stated provides a level of confidence of approximately 95%.

4.3 The Standards used are traceable to the National Standards.

4.4 The values in this certificate are correct at the time of calibration. Subsequently the accuracy will depend on such factors as the care exercised in handling, use of the instrument and the frequency of use.

4.5 The validity of this certificate expires in **Jan, 2013.**