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Sex estimation using the diagonal diameter measurements of first mandibular molars in a Sudanese sample

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Contents

List of Keywords

Sexual Dimorphism

Sudan

Adult mandibular first molars

Abstract

Sexual identification of immature skeletal remains is still a complicated issue to solve in Forensic Anthropology. Sexual dimorphism is the condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs. [(1)] The aim of this study is to evaluate the existence of sexual dimorphism in mandibular first molars. The base sample of the study includes 300 Sudanese (150 males and 150 females). Their ages ranged from 17 to 55. The mesio-buccal (MB) disto-lingual (DL) and the mesio-lingual (ML) disto-buccal (DB) surfaces of the mandibular first molars were measured using a digital Vernier caliper on plaster of Paris study casts. The data was analyzed using the t-test. The results showed statistically significant sexual dimorphisms in male and female odontometric features. The mean values of the parameters were greater in males than in females in both (MBDL and MLDB) with greater sexual dimorphism in the MBDL (MBDL dimorphism =28.672 %) than the MLDB (MLDB dimorphism =21.596 %). Conclusion: Sexual dimorphism of 1st molar teeth can aid in the identification of skeletal remains of Sudanese origin.

Declaration

I declare that “Sex estimation using the diagonal diameter measurements of first molars in a Sudanese population” is my own work, and that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Dedication

To My Supervisor: Prof. V. M. Phillips

PhD, DSC

Siddig Bashir Hag Yousif

Signed: ……

Acknowledgment

I would like to express my gratitude and appreciation to Prof. V. M. Phillips, my supervisor, for his invaluable advice and guidance from the beginning of this research as well as aiding me with his vast experience throughout the work. Moreover, I would like to extend my gratitude to my statistician Mr. Rami Khalid whose encouragement and support was of indispensable value. He shared his knowledge and ideas wholeheartedly to enrich my growth as a student, which shaped the researcher I would like to be.

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Introduction

Sex estimation has been the focus of many forensic studies and mass fatality cases, especially when there is extensive damage to bodies rendering them beyond recognition. These scenarios make the estimation of sex very difficult for the pathologist. However, due to the evolution of forensics, it is possible to use bone size in the estimation of sex when the male or female reaches adulthood. Male bones are larger than female bones due to the addition of muscle that build up on the male body during adolescence. The female pelvis has a larger sub-pubic angle to that of a male, while in males the sub-pubic area is less than 90 degrees. (1)

Other features of sexual differences between males and females are acetabulum that secure the head of the femur. These are found to be larger in males than in females. The female's chin is more pointed compared to the male's which is squarer. Males have a brow ridge while females do not. (2) Sometimes the analysis of skeletal remains is a challenge, especially in cases of mass disaster and high intensity explosions, when severe fragmentation and burning of human remains occur. In some cases, there may only be fragments of jaws with teeth.

Teeth are unique organs made up of mineralized tissues. They are the central component of the masticatory unit of the skull and can resist ante-mortem and post-mortem insults as they represent the hardest human tissue; therefore, they are considered valuable material for odonatological, anthropological, forensic medicine and genetic identity investigation. They are often used as an adjunct in solving forensic cases because of their postmortem longevity and less susceptibility to fragmentation and being more fire resistant than skeletal bones.(3)

The study of teeth is of great interest to anthropologists, biologists, orthodontists and forensic scientists because they are made of the most enduring mineralized tissues in the human body and are relatively resistant to dissolution and destruction. Various features of teeth, including their detailed morphology, crown size and root lengths differ between male and females. These differences can help a forensic scientist to identify the sex of the victims of mass disasters, since they are generally preserved even when the soft tissue and bones are destroyed. Determination of sex is significant in the cases of major disasters where bodies are often damaged beyond recognition. Sex determination builds the biological profile of the unidentified human remains; thereby, excluding about half of the population in search operations. However, it is necessary to use population specific reference data because the degree of sexual dimorphism varies between

different populations.[2] The existence of sexual dimorphism in permanent teeth is a known phenomenon observed in several investigations. Sex determination is considered an important step in reconstructing the biological profile of unknown individuals in a forensic context. Forensic anthropologists have long used teeth as an additional tool for sex determination as they resist postmortem destruction. In this case the use of population-specific data is necessary since sexual dimorphism varies between different populations. [2]

Sexual dimorphism refers to those differences in size, stature and appearance between males and females that can be applied to dental identification because no two mouths are alike.[2] Sex determination always plays a pivotal role in solving medico-legal cases as well as in anthropological studies. Sex may be determined from various parts of the body like the skull and long bones.[2] Sex determination using dental features is primarily based upon the comparison of tooth dimensions in males and females, or upon comparing the non-metric dental traits. Morphometric analysis plays an important role in determining the sex in cases of major catastrophes when the bodies are often damaged beyond recognition. Tooth size standards based on investigations can be used in age and sex determination, as human teeth exhibit sexual dimorphism. The importance of Morphometric in sex determination is reflected in various studies carried out on the subject across the globe. [4]

Aim

The aim of this study was to investigate sexual dimorphism of molar teeth in a sample of Sudanese adults for forensic identification purposes.

Objectives

To measure the degree of sexual dimorphism in permanent mandibular first molars in a sample of Sudanese patients from Khartoum dental hospital, by measuring the diagonal crown diameters of plaster of Paris study models using a Vernier caliper.

To statistically analyze the differences in size of the molars.

To determine the sexual dimorphism of the 1st molar tooth for identification purposes.

Literature Review

A study concerned with the tooth size similarities in males and females, constituted a further test of the hypothesis of X-linked mediation. One of the results of this study was that males possess larger permanent molars than females.[5]

A study was made in 1971 to demonstrate the differential direct effects on growth of genes on the human X and Y chromosomes. It concluded that the Y chromosome apparently affects tooth crown growth, and that its effect differs from that of the X chromosome. So, the sexual dimorphism observed in average tooth crown size is connected to the influence of the Y chromosome.[6]

A study of the sex differences in tooth size was done in 1974 found that on average permanent male teeth are larger than female teeth compared to the deciduous teeth.[7]

The purpose of a study in 1977 was to investigate the accuracy with which gender can be differentiated by odontometric analyses in a North Indian population. The material consisted of 445 dental casts (233M:212F) in the age group of 17-57 years. Measurements were made on the mesiobuccal, distolingual and distobuccal mesiolingual diameters by digital vernier caliper. The study established the existence of a definite statistically significant sexual dimorphism in distolingual mesiobuccal diameter of the canine and distolingual mesiobuccal diameter of second molar. [8]

A study was carried out in 1987 on sex specific correlation matrices derived from 2,650 individuals from the Solomon Islands, Melanesia. Mesiodistal; buccolingual diameters of all permanent teeth from one side were used, excluding third molars. Analysis disclosed significant sex dimorphism. [9]

A study concerning the examination of the mesiodistal; buccolingual crown dimensions in three populations; 57 subjects (35 boys and 22 girls) from Iowa City, 54 subjects (30 boys and 24 girls) from Alexandria, Egypt, and 60 subjects (26 boys and 34 girls) from Chihuahua, Mexico. All subjects had normal Class I occlusion, with no history of orthodontic treatment. Comparisons of single teeth as well as groups of teeth were performed between boys and girls within and between the two populations. The findings from this investigation indicated the following: (1) Differences between antimeres are of small magnitude and of no statistical significance; (2) All

populations have significant differences in tooth dimensions between the sexes with boys having larger canines and first molars; (3) There is greater variation in the buccolingual than in the mesiodistal dimensions among the three populations; (4) There is greater similarity in tooth dimensions among the boys from the three populations than among the girls, but the magnitude of these differences is considered to be of little clinical significance; and (5) Standards for the buccolingual diameters were developed for the three populations. As a result, it was concluded that prediction equations used for space analysis in the mixed dentition to determine tooth size-arch length discrepancies in the Iowa population can also be used for persons from Egypt and from the northern part of the Mexican Republic, with some suggested modifications. [10]

Sexual dimorphism in the crown components in the second deciduous molar (dm2) and the first permanent molar (M1) of the dental casts taken from Chinese living in Kaohsiung (Taiwan) was investigated. Mesiodistal and buccolingual crown diameters, and 4 main-cusp sizes in the maxillary molars and mesiodistal diameters of the trigonid and talonid in the mandibular molars were measured using a digital caliper. Percentage sexual differences were calculated, the mean values of males were larger than females. [11]

A study was performed to investigate the accuracy with which sex can be differentiated by odontometric analyses in the Swedish population. The sample consisted of 58 dental casts, 29 male and 29 female, ranging in age from 14 to 38 (mean age 19) years. Measurements were made on the mesiodistal, buccolingual, mesiobuccal distolingual and distobuccal mesiolingual diameters. The mean diameters for males were larger than those for females in all variables and 27 out of the 56 differences were statistically significant ($p < 0.05$). The upper canine had significant mean differences in all measurements. Lower canines, second upper and lower premolars, upper second molars and the lower first molars all had significant mean values in three of four variables. These findings support the usefulness of especially the canines in sex determination by odontometric analyses. [12]

In Turkey a study was conducted to test whether diagonal measurements can facilitate more accurate measurements. The results of diagonal measurements of dental casts taken from 30 males and 30 females were evaluated by discriminant function statistics. Seven of the 14 measurements on the maxilla and 10 of the 14 measurements on the mandible were found to be significantly greater in males. According to the results of the stepwise discriminant function

statistics, the most contributory measurements to the function were the upper first incisor mesiobuccal distolingual (MBDL), distobuccal mesiolingual, lower second incisor MBDL, and lower canine MBDL. The highest reliability was obtained in MBDL measurements. It was realized that diagonal measurements of teeth, especially of canines, revealed clear dimorphic differences. Classification accuracy was found to be 83.3% for the total sample, 78.3 for the upper jaw, and 85.0% for the lower jaw. The accuracy rate was higher in the lower teeth. This explains why this research is considered to be of great value concerning diagonal measurements, which is an accurate method, particularly when employed for the front teeth. [13]

A study was carried out to investigate sexual dimorphism in the Nepalese dentition, showed the greatest dimorphism in the canines, followed by the buccolingual dimension of maxillary first and second molars. Overall, the maxillary teeth and buccolingual dimensions showed greater differences. However, less than half of the measured variables (46.4%) showed statistically significant differences between the sexes and the magnitude of sexual dimorphism reduction when compared to other populations. Moreover, reverse dimorphism, where females showed larger teeth than males, was observed in the mesiodistal dimension of mandibular second premolars. This reflects reduction in sexual dimorphism throughout human evolution and the consequent overlap of tooth dimensions in modern males and females. A specific purpose of the study was to develop discriminant functions to facilitate sex classification. A group of functions were developed considering the possibility of missing teeth and/or jaws in forensic scenarios. The functions permitted moderate to high classification accuracy in sexing (67.9% using maxillary posterior teeth; 92.5% using teeth from both jaws). [14]

A study was performed on a sample of 100 dental casts of a South Indian population in the age group 14-20 in an attempt to assess the dimorphism of human permanent maxillary and mandibular canines and to evaluate the possibility of dimorphism of the canines being used as a valid tool in the forensic and legal identification of an individual. The mesiodistal and buccolingual measurements were subjected to statistical analysis, using the t-test to determine whether significant differences exist between tooth size in males and females. The study revealed that the mean values of the buccolingual and mesiodistal dimensions of the mandibular left canine were greater in females than in males, and the mean values of the mesiodistal dimensions of the mandibular right canine in females were greater than in males in the given sample. The

finding could be attributed to evolution, resulting in a reduction in sexual dimorphism and causing an overlap of tooth dimensions in modern males and females. [15]

A research concerning sexual dimorphism in permanent maxillary molars of Black South African using plaster of Paris study models (105 females and 130 males) showed significant sexual dimorphism in both maxillary first and second molars. [16]

In India a study was undertaken investigating sexual dimorphism in the permanent maxillary first molar of the Haryana population. The sample consisted of 100 females and 100 males. The diameters measured were the mesiodistal the buccolingual dimensions of the maxillary first molar. The results showed significant sexual dimorphism. The first group (intraoral measurements) showed the greatest sexual dimorphism (5.34%) for the right maxillary first molar; the second group (study cast group) showed the greatest sexual dimorphism (5.54%) for the left maxillary first molar. [17]

A study was performed to examine the degree of sexual dimorphism in permanent teeth of modern Greeks. A total of 839 permanent teeth in 133 individuals (70 males and 63 females) from the Athens Collection were examined. Mesiodistal and buccolingual crown and cervical diameters of both maxillary and mandibular teeth were measured. It was found that males have bigger teeth than females and in 65 out of 88 dimensions measured, male teeth exceeded female teeth significantly ($P<0.05$). Canines were the most dimorphic teeth followed by first premolars, maxillary second premolars and mandibular second molars. Although other teeth were also sexually dimorphic they did not show a statistically significant difference in all dimensions. The most dimorphic dimension was the buccolingual cervical diameter followed by the buccolingual crown diameter. A comparison of sexual dimorphism in teeth between different populations showed that it differs among different groups. European population groups presented the highest degree of sexual dimorphism in teeth and Native South Americans the lowest. [3]

A study of the sex differences in tooth size was carried out to investigate the sexual dimorphism of African Americans, using the diagonal diameters of permanent molars' crowns. The research comprised one hundred and three (50 females and 53 males). Their age group ranged from 16 to 66 years. Four measurements for each left maxillary and mandibular molar crowns were used; mesiolingual distobuccal crown diameter, mesiobuccal distolingual crown diameter, mesiobuccal

distolingual cervical diameter and mesiolingual distobuccal cervical diameter. Analyses of the results showed that males were significantly different from females in the case of the maxillary first, second and third molars as well as the mandibular first molar. [4]

Another study in India which derived data from a large sample of males and females, using a digital caliper, buccolingual and mesiodistal dimensions of all permanent teeth (except third molars) were measured on 600 dental casts (306 females, 294 males) of young adults (18-32 years). The analyses revealed that canines were the most sexually dimorphic teeth followed by molars. All tooth variables were larger in males, with 51/56 (91.1%) being statistically larger ($p < 0.05$), reflecting the importance of using a large sample to quantify sexual dimorphism in tooth dimensions. [18]

A subsequent study on sexual dimorphism investigated the mesiodistal dimension of permanent maxillary incisors and canines in the Chilean population. This was done using 303 dental casts (177 females and 126 males) from the Nacional de Ortodoncia, Chile. The results showed that there are significant sex differences in the Chilean population. [19]

A study in 2017 investigated the utility of cervical measurements for sex estimation through discriminant analysis. The permanent molar teeth of 75 skeletons from the Hasanlu site in north-western Iran were studied. Cervical mesiodistal and buccolingual measurements were taken from both maxillary and mandibular first and second molars. Discriminant analysis was used to evaluate the accuracy of each diameter in assessing sex. The results showed that males had statistically larger teeth than females for maxillary and mandibular molars and cervical mesiodistal and buccolingual measurements ($P < 0.05$). The range of classification rate was from 78.4% to 87.1% for the original and 78.4% to 85.5% for cross-validated data. The most dimorphic teeth were the maxillary and mandibular second molars, providing 87.1% and 86.1% correct classification rate respectively. The data generated from the study suggested that cervical mesiodistal and buccolingual measurements of molar teeth can be useful and reliable for sex estimation in Iranian archaeological populations. [20]

A study was done to analyze dental dimensions and sexual variation in living Turks and develop forensic techniques to identify human remains from the teeth when any other technique is not available or not reliable. The study was composed of Ankara University dental students (50 male

and 50 female casts, average age of 21 years). Buccolingual breadths from 14 teeth were taken from the left side and analyzed using the discriminant function statistics. An intra-observer error test did not indicate any statistically significant difference between any two measurements. Results of the study revealed that males exceeded females significantly in dimensions. [21]

A study was made to explore the utility of crown and cervical and diagonal measurements of molars in sex assessment when used separately. A total of 254 permanent molars (excluded third molars) from 101 individuals (51 males, 50 females) from the Athens Collection were examined. Stepwise discriminant analysis was used to evaluate the accuracy of each diameter group in assessing sex. It was found that the accuracy ranges from 65.5 to 88.4 %. Cervical diagonal diameters are the most accurate followed by crown diagonal diameters, and crown and cervical diameters. Therefore, the high classification accuracy of diagonal diameters shows that these measurements are more reliable for sex determination. [22]

A study was based on the skeletal remains for sex assessment of 149 individuals from three protohistoric populations in close temporal and geographic proximity in Abruzzo region (central-southern Italy). The mandibular canine was the tooth with the greatest sexual dimorphism in adults, followed by both maxillary and mandibular first and second molars. [23]

Materials and methods

The sample consisted of 300 patients (150 males and 150 females). The two diagonal diameters of the first mandibular molar were measured and documented in each individual. (Appendix 2 page 44).

The patients' ages ranged from 17 to 55 years old with at least one sound mandibular tooth. The patients were chosen randomly.

The measurements of the two longitudinal diameters were as follow:

a. Mesiobuccal to distolingual (MBDL by choosing the most distant Mesiobuccal point to the most distant Distolingual point).

b. The mesiolingual to the distobuccal (MLDB by choosing the most distant Mesiolingual point to the most distant Distobuccal point).

The reason for choosing the most distant points longitudinally was to obtain the longest dimension in each crown by setting two fixed points in each longitudinal diameter (Fig. 1).

Both longitudinal diameters (MBDL and MLDB) were measured in millimeters. A digital Vernier caliper was used to measure the diameter of the 1st mandibular molar of either the left or right side of the mandible after ensuring that the tooth was sound. In cases where carious or dental restorations were present the tooth from the other side was chosen (Fig. 2).

Exclusion criteria:

Patients with a medical history that may affect the tooth morphology.

Teeth that were carious or had dental restorations.

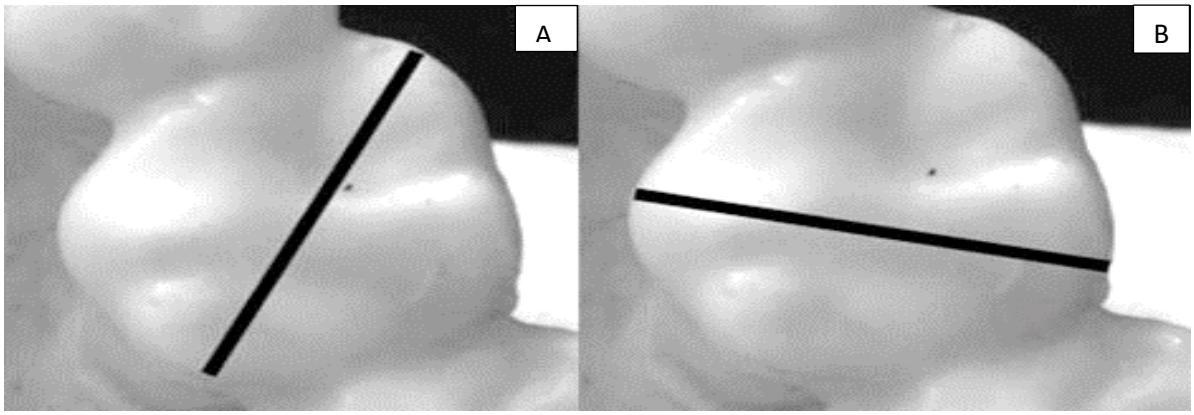


Fig 1: (A) Mesiobuccal; Distolingual by choosing the most distant Mesiobuccal point to the most distant Distolingual point. (B) Measurement of Mesiolingual; Distobuccal by choosing the most distant Mesiolingual point to the most distant Distobuccal point. [(1)]

Fig 2: The measurement of the diameters (in millimeters) using a digital Vernier caliper

For the analysis of the data, a Statistical Package for Social Sciences software, version 21.0 (IBM SPSS Inc., Chicago, IL) was used. Initially, all information was coded into variables. Both descriptive and inferential statistics involving the Independent T-test and Mann-Whitney U Test were used to present the results.

Ethical Approval

Ethical approval and permission to carry out the study was sought from the Dental Research and Senate Research Ethics committees of the University of the Western Cape (Appendix 3 page 55). No financial or personal gain was received from this study. There was no vested interest in any of the material used.

A permission letter was sent to the first official at Khartoum dental teaching hospital and permission was obtained to carry out this study.

Conflict of interest statement

There was no conflict of interest.

Budget

There were no financial implications as all materials were supplied by the researcher.

Data Analysis

The degree of sexual dimorphism was determined for each of the diagonal diameter measurements and calculated using the following formula to calculate the percent of sexual dimorphism:

{(male mean - female mean)\ female mean} x 100 [24]

Statistical analysis of the data was conducted initially for both males and females together to determine if the gender differences were significant.

The data was structured in a Microsoft Excel program. The database was imported into a statistical package of the social science (SPSS) version 21 (IBM, UAS) for windows to perform the statistical analysis.

Table 1: Shows the age distribution of the total number of patients (n = 300), the base sample comprised (150 males and 150 females) with age range from 17 years old to 55 years old.

Table 1

Descriptive Statistics	Number	Minimum	Maximum	Median	Mean
Total age (Years)	300	17	55	34.5	34.91
Males age (Years)	150	17	55	35.5	36.21
Female age (Years)	150	17	50	34	33.6

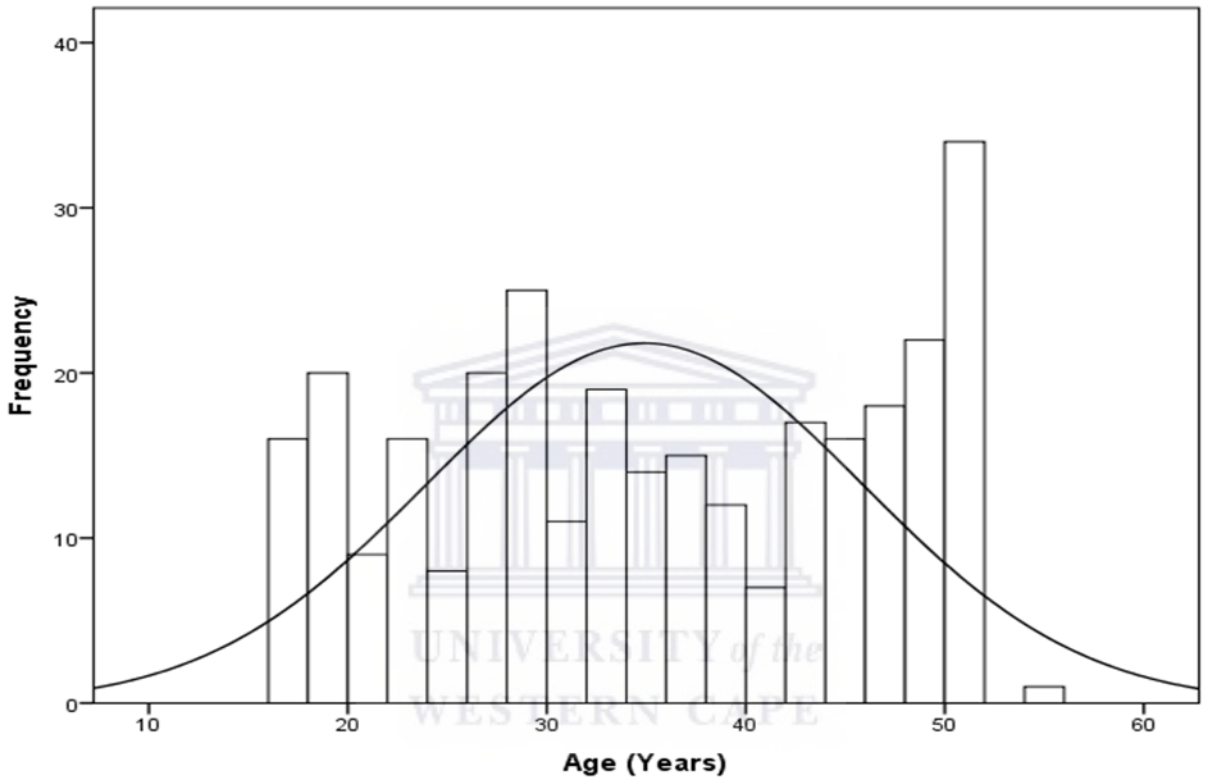
As seen in table 1 the sample can be considered as a large sample when compared with other previous studies from another parts of the world as shown in the literature review. [3] [4] [10] [12]

The importance of using a large sample is to quantify sexual dimorphism among this sample of Sudanese. [18]

Graph A

Shows the frequency of age in the total sample which is 300 participants (n= 150 males +150 females)

Graph A

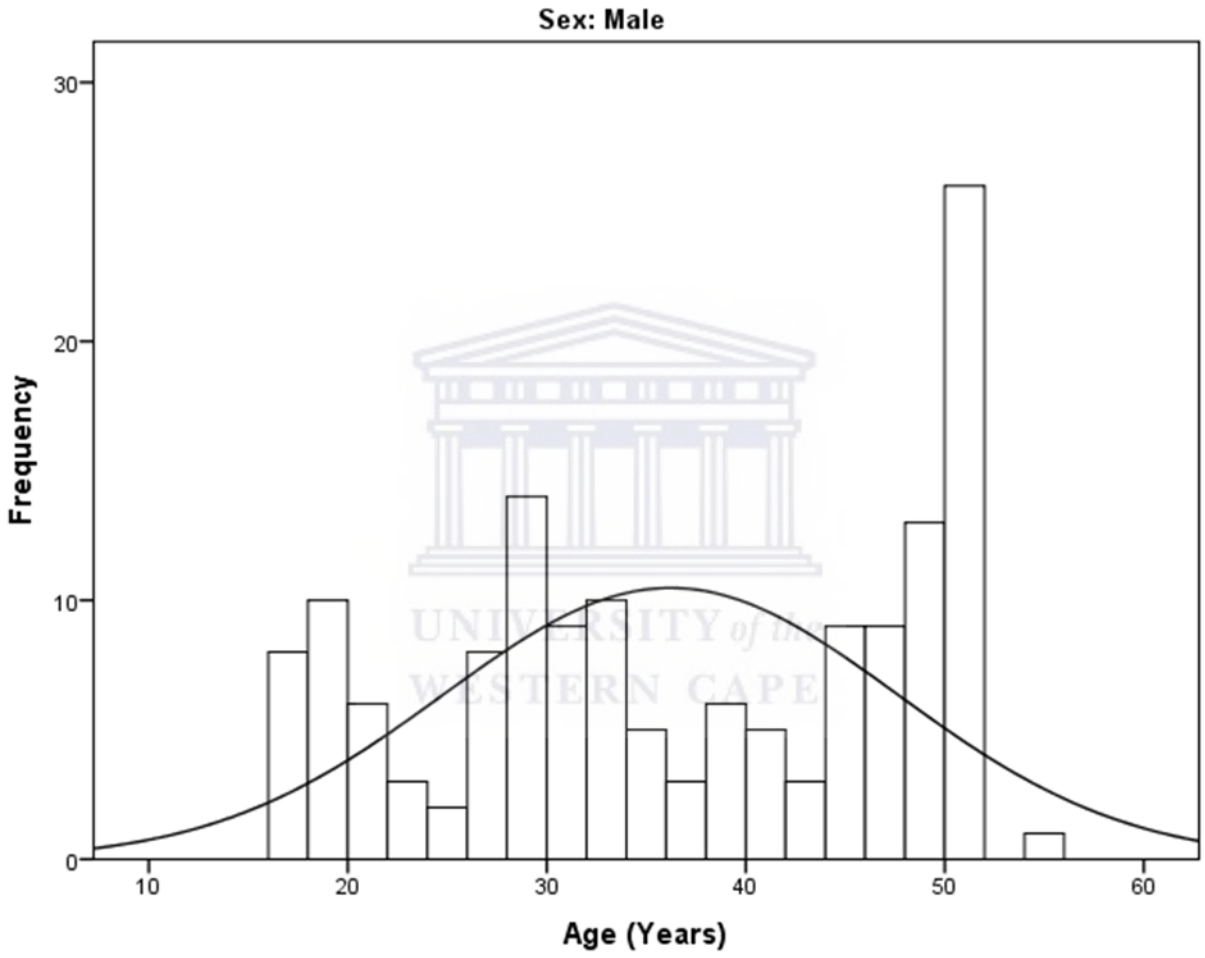


The mean age in the sample is 34.91 as shown in graph A, the age of the total sample ranges between 17 to 55 years old.

Graph B

Shows the frequency of age in Males as the total sample of males is 150, with high frequency in the group age between (50 to 60 years old)

Graph B

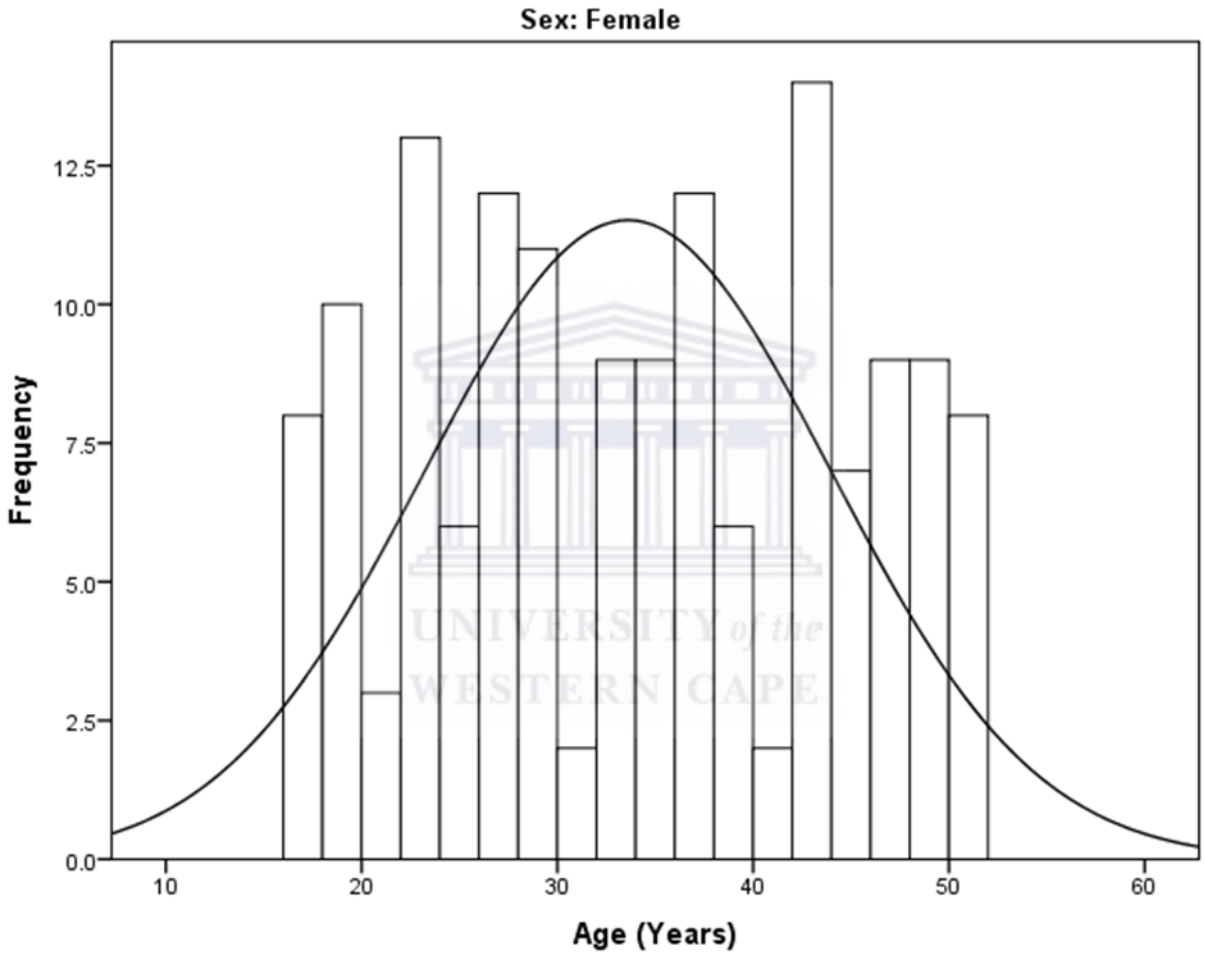


The males mean age is 36.21 and the male sample age ranges between 17 to 55 years old.

Graph C

Shows the frequency of age in Females as the total sample of females is 150, with high frequency in the group age between (40 to 50 years old)

Graph C



The females mean age is 33.6 and the female sample age ranges between 17 to 50 years old.

Table 2: Shows the total MBDL diameter minimum (8.11 mm) which is a female reading, maximum MBDL diameter (12.99 mm) which is a male reading, median and mean in both females and males with a standard deviation in males of 0.63136 and in females 0.67909.

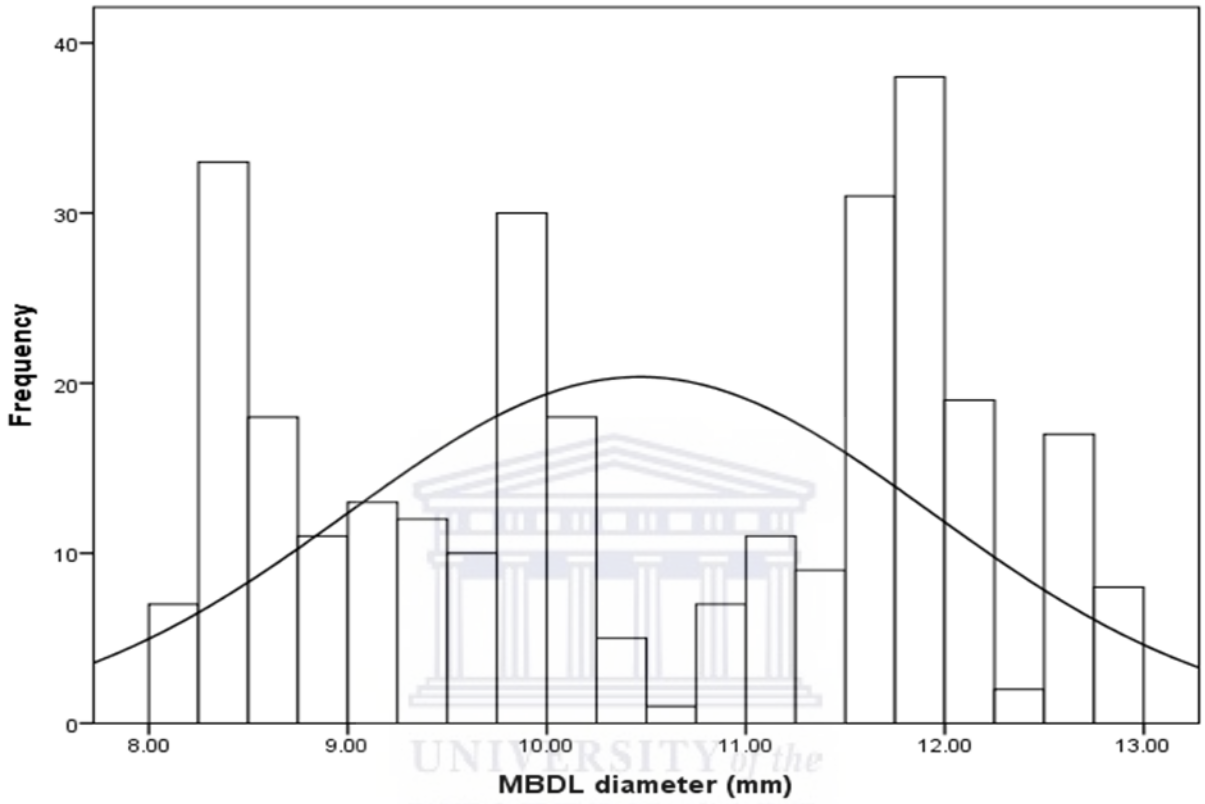
Table 2.

Descriptive Statistics	Number	Minimum	Maximum	Median	Mean	Std. Deviation
Total MBDL diameter (mm)	300	8.11	12.99	10.195	10.4679	1.46902
Male MBDL diameter (mm)	150	9.89	12.99	11.81	11.7809	0.63136
Female MBDL diameter (mm)	150	8.11	10.94	9.15	9.155	0.67909

Graph D

Shows the frequency of the total MBDL (male/female) diameter in mm

Graph D

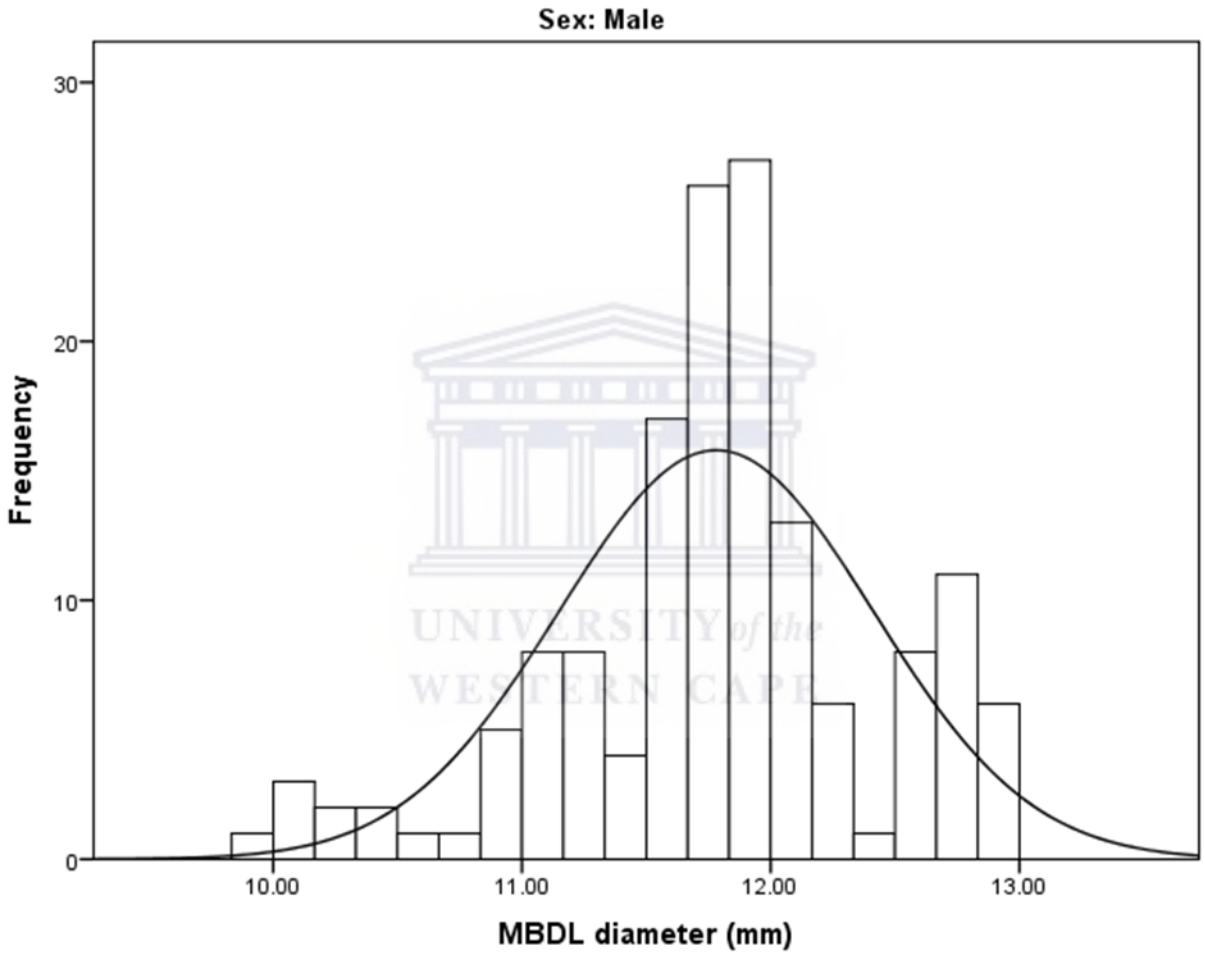


The MBDL diameter ranges between 8.11 mm to 12.99 mm, with mean of 10.46 mm.

Graph E

Shows the frequency of the male MBDL diameter in mm, with minimum (9.89) and maximum (12.99).

Graph E

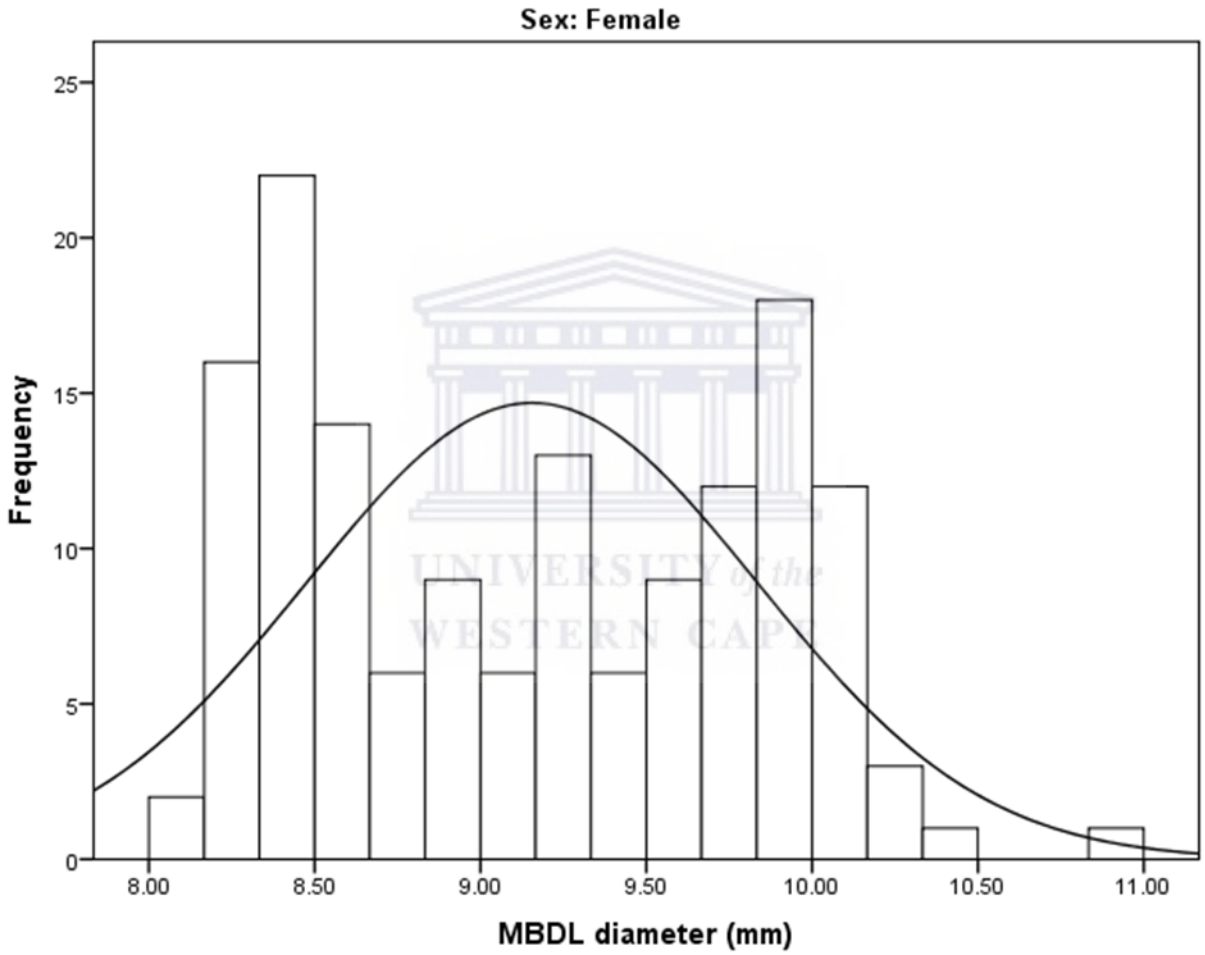


The male mean MBDL is 11.7809 mm.

Graph F

Shows the frequency of the female MBDL diameter in mm, with minimum (8.11) and maximum (10.94).

Graph F



The female mean MBDL is 9.155 mm.

Table 3: Shows the MLDB diameter minimum (8.02 mm) which is a female reading, maximum (12.01 mm) which is a male reading, median and mean in both females and males with a Standard Deviation in males of 0.57361 and in females 0.65856.

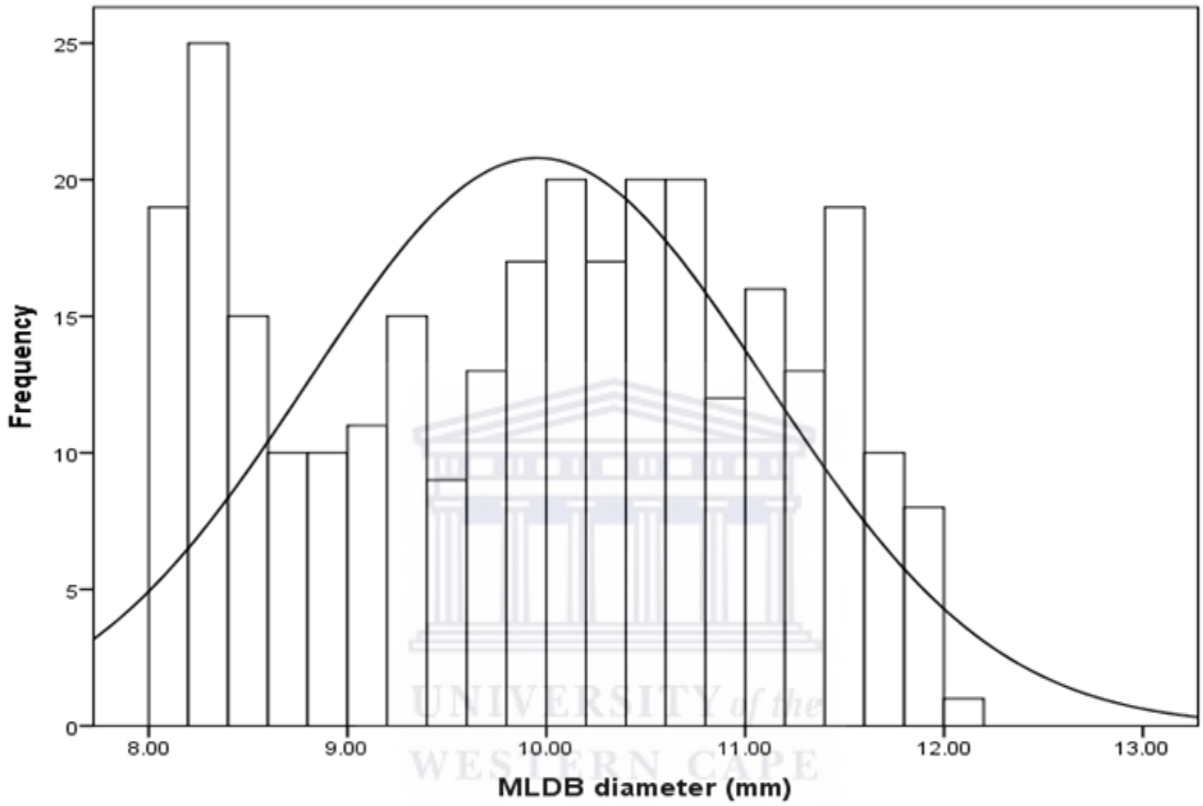
Table 3

Descriptive Statistics	Number	Minimum	Maximum	Median	Mean	Std. Deviation
MLDB diameter (mm)	300	8.02	12.01	10.04	9.9536	1.15091
Male MLDB diameter (mm)	150	9.22	12.01	10.92	10.9238	0.57361
Female MLDB diameter (mm)	150	8.02	10.22	8.95	8.9833	0.65856

Graph G

Shows the frequency of the total MLDB (male/female) diameter in mm

Graph G

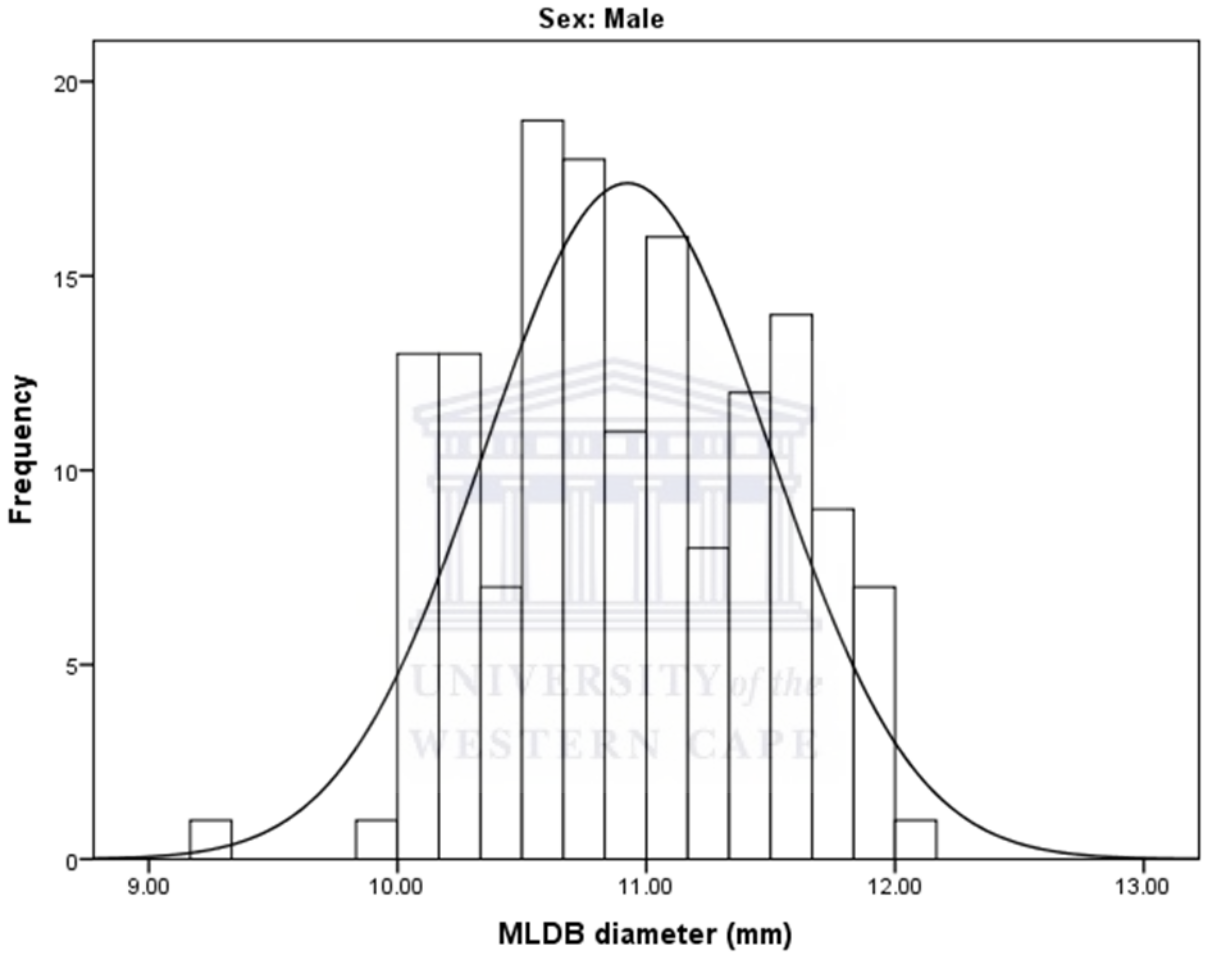


The MLDB diameter ranges between 8.02 mm to 12.01 mm, with mean of 9.95 mm.

Graph H

Shows the frequency of the male MLDB diameter in mm, with minimum (9.22) and maximum (12.01).

Graph H

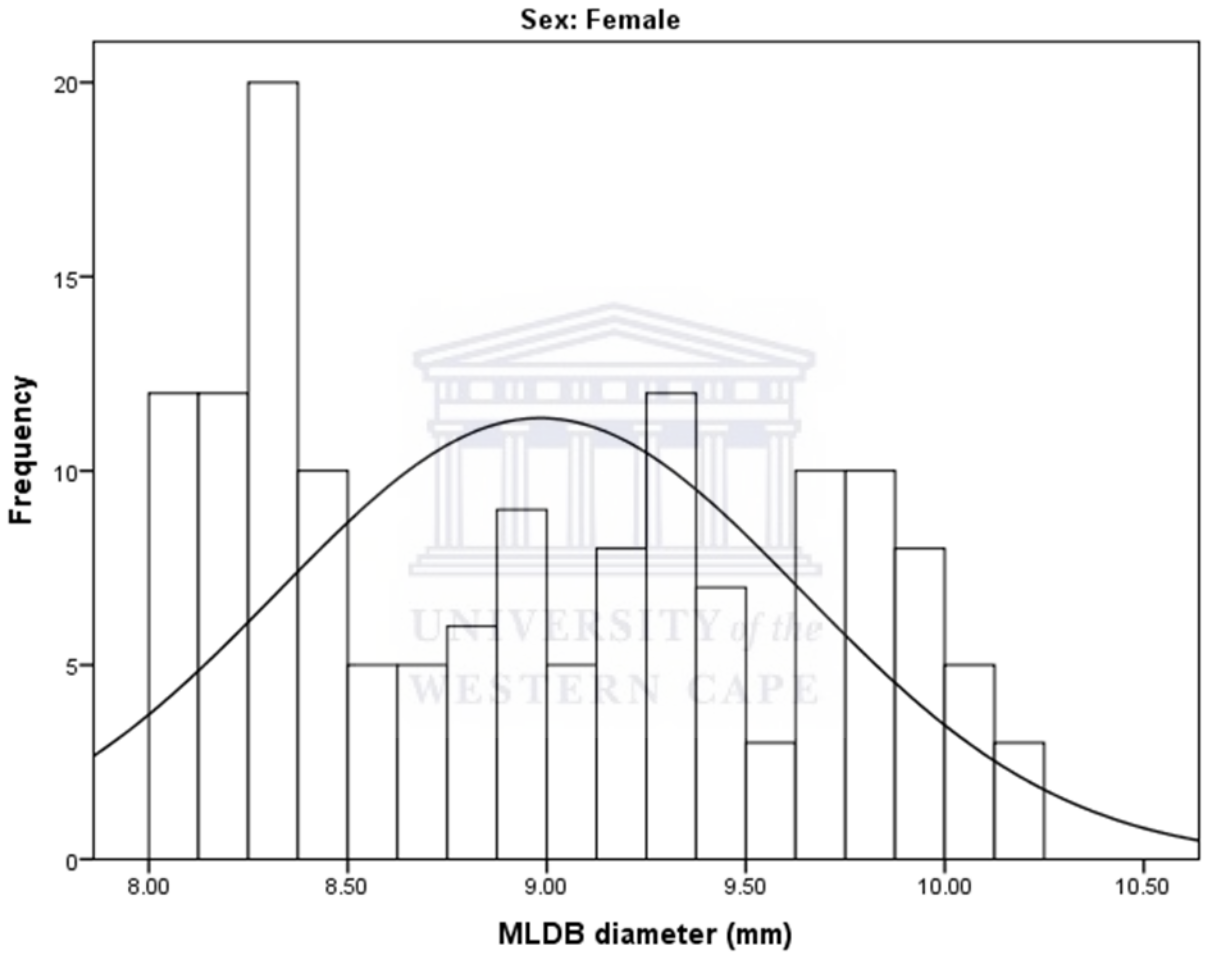


The males mean MLDB 10.9238 mm.

Graph I

Shows the frequency of the female MLDB diameter in mm, with minimum (8.02) and maximum (10.22).

Graph I



The females mean MLDB 8.9833 mm.

Table 4: Indicates the Independent T-test with a Standard Error Mean of (0.04683) for males and (0.05377) for females, the p value <0.05 is considered statistically significant.

Table 4: The MLDB diameter (mm).

Independent T-test				
Variables		MLDB diameter (mm)		
Sex	Number	Mean	Std. Deviation	Std. Error Mean
Male	150	10.9238	0.57361	0.04683
Female	150	8.9833	0.65856	0.05377
P value = <0.01**				

Table 5: Shows the Mann-Whitney U-test of the differences in the MBDL diameter in males and females.

Table 5

Mann-Whitney U-Test			
Variables		MBDL diameter (mm)	
Sex	Number	Mean Rank	Sum of Ranks
Male	150	224.94	33741.5
Female	150	76.06	11408.5
P value = <0.01**			

Table 6: Shows the MBDL diameter Independent T-test, with a Standard Error Mean of 0.05155 for males and 0.05545 for females.

Table 6

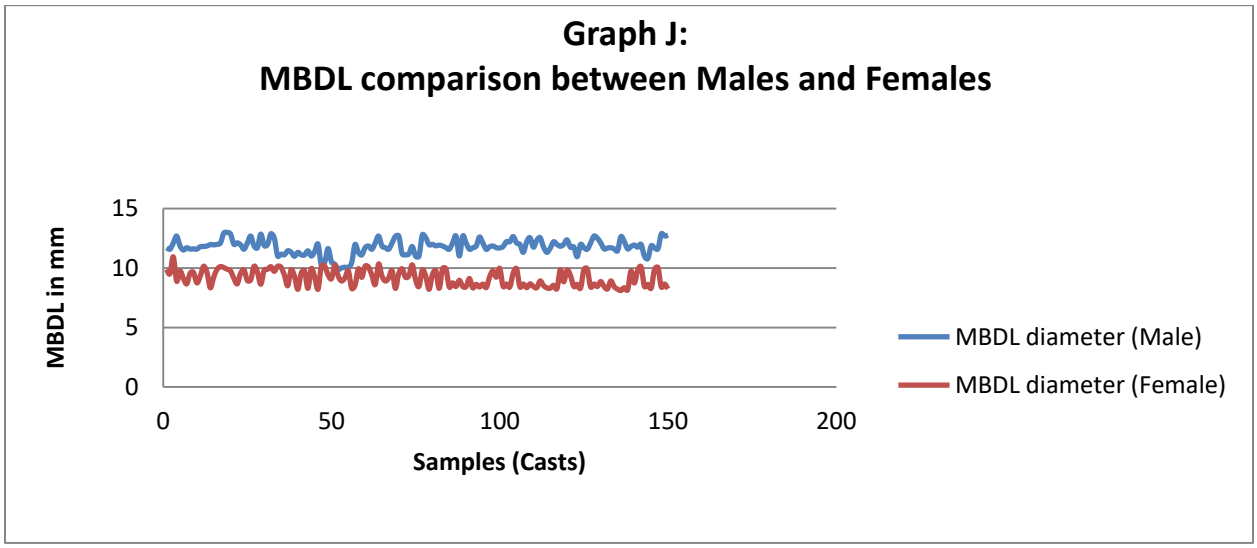
Independent T-test				
Variables		MBDL diameter (mm)		
Sex	Number	Mean	Std. Deviation	Std. Error Mean
Male	150	11.7809	0.63136	0.05155
Female	150	9.155	0.67909	0.05545
P value = <0.01**				

Table 7: Shows the Mann-Whitney U-test of MLDB diameter in males and females with a p value < 0.05 that is statistically significant.

Table 7

Mann-Whitney U-Test			
Variables		MLDB diameter (mm)	
Sex	Number	Mean Rank	Sum of Ranks
Male	150	224.53	33679.5
Female	150	76.47	11470.5
P value = <0.01**			

Graph J



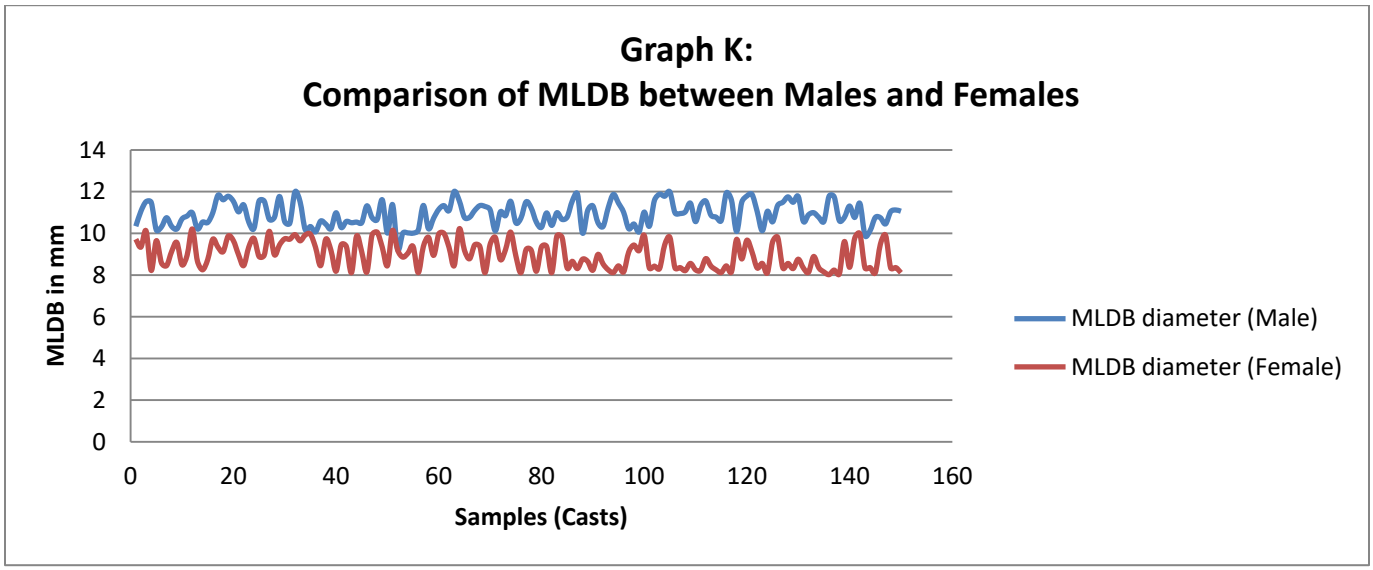
The blue line in the graph represents the MBDL diameters in the male's sample (n=150) compared to the red line of the females:

1-The first group (females) ranges between (8.11 mm) to (9.88 mm).

2-The second group (males) ranges between (10.95 mm) to (12.99 mm).

3-The area between (9.89 mm) to (10.94 mm) is a combined Female and Male area.

Graph K



The blue line represents the Males MLDB diameters in the male sample (n=150) compared to the red Females MLDB diameters (n=150):

1. The first group (female) ranges between (8.02 mm) to (9.21 mm).
2. The second group (male) ranges between (10.22 mm) to (12.01 mm).
3. The area between (9.22 mm) to (10.21 mm) is a combined female and male area.

Results

The mean values of the parameters were greater in males than in females in both MBDL and MLDB, Males MBDL Mean = 11.780mm, Females MBDL Mean = 9.155mm, Males MLDB Mean = 10.923mm, Females MLDB Mean = 8.983mm

Sexual Dimorphism

The raw data in the appendix was used to calculate the sexual dimorphism

{(male mean - female mean)\ female mean} x 100

MLDB dimorphism = 21.596 %

MBDL dimorphism =28.672 %

Sexual dimorphism can be seen in both crown diameters; Mesiobuccal Distolingual and Mesiolingual Distobuccal.

Greater sexual dimorphism was found in the MBDL (MBDL dimorphism =28.672 %) than in the MLDB (MLDB dimorphism =21.596 %).

The Males MLDB diameter ranged between (9.22 mm) to (12.01 mm).

The Females MLDB diameter ranged between (8.02 mm) to (10.22 mm).

The Males MBDL diameter ranged between (9.89 mm) to (12.99 mm).

The Females MBDL diameter ranged between (8.11 mm) to (10.94 mm).

The results were statistically significant ($P < 0.05$). The mean difference for MBDL and MLDB was 0.05 and 0.04, respectively, which may not have practical significance.

Discussion

The age of the total sample in this recent study ranges between 17 to 55 years old, with median age of 34.5 and mean age of 34.9.

The males age ranges from 17 to 55 years old, with median age of 35.5 and mean age 36.2.

The females age ranges from 17 to 50 years old, with median age of 34 and mean age 33.6.

Therefor the total sample can be categorized as adults.

The base sample of the study includes 300 Sudanese (150 males and 150 females), which can be considered as a large sample in order to reflect the importance of using a large sample to quantify sexual dimorphism in tooth dimensions. [18]

As seen in table 1 the sample can be considered as a large sample when compared with other previous studies from another parts of the world as shown in the literature review for example:

(Macaluso 2010) study (n=235). [16]

(Kazzazi and Kranioti 2017) study (n=80). [20]

(İşcan and Kedici 2003) study (n=100). [21]

In Angadi et al 2013 study, the base sample was large (n=600) and that reflected that all tooth variables were larger in males, with (91.1%) being statistically larger ($p < 0.05$). [18]

The opposite can be observed in the Macaluso 2010 study, as the most accurate result (74%) was obtained when all cusp diameters from both molars were used. However, less accurate results (70.0%) were achieved when selecting dimensions from only one molar. [16]

In this recent study the reason of choosing the most distant points longitudinally was to obtain the longest dimension in each crown by setting two fixed points in each longitudinal diameter. Many studies were made to explore the utility of crown diagonal measurements of molars in sex assessment when used separately, the high classification accuracy of diagonal diameters showed that these measurements are more reliable for sex determination. [13,22]

In this study, the mean values of the parameters were greater in males than in females in both (MBDL and MLDB) with greater sexual dimorphism in the MBDL (MBDL dimorphism =28.672 %) than the MLDB (MLDB dimorphism =21.596 %).

The Kazzazi and Kranioti 2017 study used cervical mesiodistal and buccolingual measurements of permanent maxillary and mandibular first and second molars for sex estimation. The greatest difference in percentage of sexual dimorphism was observed in the maxillary second molar. The percentage of sexual dimorphism for the maxillary second molar in the study was 14.14% (mesiodistal) and 13.23% (buccolingual). [20]

Also the Sonika et al 2011 study on the Haryana population revealed that the first group (intraoral measurements) showed the greatest sexual dimorphism (5.34%) for the right maxillary first molar; the second group (study cast group) showed the greatest sexual dimorphism (5.54%) for the left maxillary first molar. [17]

Both studies Kazzazi and Kranioti 2017 and Sonika et al 2011 indicates lower values in sexual dimorphism when compared with the recent study.

As shown in the literature review, many earlier studies referred to the first molar as the second tooth that showed the greatest sexual dimorphism after the canines, especially when larger samples were taken to quantify the dimorphism. [3] Even in studies with smaller samples like Acharya et al. 2007 and Boaz et al. 2009 [4, 5] the first molar is the second tooth that shows sexual dimorphism after the canines. This study showed sexual dimorphism of the mandibular first molars; no other teeth were measured in this sample of Sudanese people.

When comparing this study to other recent studies that have investigated sexual dimorphism in mandibular first molars, for example, Kazzazi et al. 2017 [6] study, there are similarities, as both indicate sexual dimorphism in the mandibular first molar.

Accordance in results is evident when comparing this recent study with earlier ones that show that in most contemporary human populations, males possess larger permanent molar crowns than females. [5, 6, 8, 11, 21, 22, 23, 24] Some of these old studies applied a biological and statistical approach e.g. Alvesalo 1971 [10], while in this recent study only statistical approach was applied.

When comparing this study to other studies that investigated the sexual dimorphism in first molars in other populations around the world, we find accordance in results, for example, in the African Americans and Black South Africans we find sexual dimorphism in first molars, especially in the maxillary first molars. [7, 16] Similarity in the samples can be found as all of these study samples originated from Africa.

This recent study also shows that there is no reduction in sexual dimorphism causing an overlap of tooth dimensions in modern Sudanese males and females when compared to Acharya and Mainali 2007 [14] and Boaz et al. 2009 [15] studies, which reflected reduction in sexual dimorphism observed through human evolution and the consequent overlap of tooth dimensions in modern males and females.

In this recent study the minimum male MBDL diameter was 9.89 mm, while the minimum female MBDL diameter was 8.11mm. The maximum male MBDL was 12.99mm, compared to the female which was 10,94mm.

The minimum male MLDB diameter was 9.22mm, and the female minimum MLDB diameter was 8.02mm. The maximum male MLDB diameter was 12.01mm and the female maximum was 10.22mm.

According to these results each diagonal diameter has three ranges of readings that can help in establishing the sexual identity among Sudanese adults:

- MBDL diameter

A. Range between (8.11 mm) to (9.88 mm) is a female range.

B. Range between (10.95 mm) to (12.99 mm) is a male range.

C. Range between (9.89 mm) to (10.94 mm) is a combined Female and Male range.

-MLDB diameter

A. Range between (8.02 mm) to (9.21 mm) is a female range.

B. Range between (10.22 mm) to (12.01 mm) is a male range.

C. Range between (9.22 mm) to (10.21 mm) is a combined female and male range.

These findings can be helpful for forensic identification purposes among Sudanese population
This study established the existence of statistically significant sexual dimorphism in mandibular first molars in a Sudanese population sample.

Conclusion

There is a significant sexual dimorphism in the dimensions of the mandibular first molars in this sample of the Sudanese population. These results will be useful in the identification process of human remains in Sudan.

This study is the first to investigate the sexual dimorphism of molar teeth in a Sudanese population sample. The importance of sexual dimorphism emerges from their individuality which can be used in estimating the sex identity (Male / Female). The emerging field of forensic odontology in the Sudan relies on an inexpensive and easy means of identification of persons using fragmented jaws and dental remains. It is in such situations that the dentist can be called upon to render expertise in forensic science.

In order to improve the success in determining sex, it is best to combine several different methods that may be beneficial with regard to genetic, legal and forensic applications where possible, especially when the ante-mortem data pertaining to sex are not available. This occurs most commonly in archaeological analysis.

Recommendations

Further studies in this domain could focus on the following:

a. Extending this study by utilizing a larger sample of Sudanese.
b. Establishing if there are differences in tooth size in the various ethnic groups in the Sudan.
c. Extending the study to investigate if there is sexual dimorphism of the deciduous teeth of Sudanese children.
d. Sex estimation can still be notoriously difficult in individuals between 16 -18 years, since the secondary sexual characteristics have not yet been fully established. The timing of sexual dimorphic characteristic development varies not only between populations but within populations as well; thus, any future study should be subdivided into young adults and elder adults.

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Appendix 1

Permission letter

To the medical director at Khartoum dental teaching hospital

Mr.....

I am Dr. Siddig Bashir Hag Yousif, and I am sending you this letter to request your approval and permission to use your hospital resources of dental impressions and casts, contained in the archives in your custody. I also need to inform you that all patients' information and data will be treated with confidentiality and will not be published.

Dr. Siddig Bashir

Appendix 2

Male				
cast	**sex**	**age**	**MBDL diameter**	**MLDB diameter**
1	M	33	11.71	10.34
2	M	40	11.58	11.06
3	M	17	12.10	11.52
4	M	19	12.69	11.49
5	M	33	11.85	10.16
6	M	45	11.51	10.31
7	M	34	11.71	10.75
8	M	50	11.59	10.33
9	M	32	11.61	10.21
10	M	19	11.59	10.69
11	M	18	11.79	10.83
12	M	17	11.81	10.99
13	M	50	11.85	10.21
14	M	50	11.97	10.54
15	M	34	11.95	10.52
16	M	28	11.99	10.99
17	M	39	12.10	11.83
18	M	50	12.94	11.61
19	M	19	12.99	11.78
20	M	32	12.86	11.54
21	M	46	12.00	11.03
22	M	29	12.12	11.37
23	M	20	11.95	10.54
24	M	31	11.58	10.23
25	M	29	12.10	11.55
26	M	49	12.69	11.55
27	M	38	11.85	10.67
28	M	35	11.71	10.77

29	M	50	12.85	11.77
30	M	29	11.89	10.56
31	M	45	11.98	10.49
32	M	46	12.88	11.99
33	M	36	12.54	11.51
34	M	26	11.01	10.17
35	M	17	11.17	10.33
36	M	50	11.11	10.07
37	M	39	11.45	10.59
38	M	43	11.33	10.44
39	M	29	10.99	10.22
40	M	50	11.32	10.99
41	M	46	11.11	10.28
42	M	49	11.10	10.57
43	M	28	11.45	10.51
44	M	47	11.01	10.54
45	M	29	11.37	10.51
46	M	25	12.01	11.32
47	M	39	10.22	10.76
48	M	50	10.48	10.66
49	M	19	11.65	11.61
50	M	17	10.51	10.01
51	M	44	10.32	11.38
52	M	55	9.89	9.22
53	M	29	10.01	10.01
54	M	29	10.07	10.02
55	M	30	10.05	10.01
56	M	48	10.44	10.15
57	M	29	11.98	11.34
58	M	26	11.32	10.22
59	M	37	11.10	10.73
60	M	49	11.71	11.15

61	M	20	11.85	11.33
62	M	30	11.58	11.09
63	M	49	12.10	12.01
64	M	40	12.69	11.56
65	M	33	11.85	10.76
66	M	50	11.71	10.77
67	M	50	11.58	11.10
68	M	43	12.10	11.33
69	M	50	12.67	11.29
70	M	32	12.69	11.13
71	M	50	11.19	10.12
72	M	33	11.11	11.03
73	M	27	11.19	10.85
74	M	49	11.81	11.54
75	M	40	10.99	10.51
76	M	50	10.99	10.73
77	M	47	12.78	11.51
78	M	26	12.55	11.22
79	M	49	11.96	10.54
80	M	19	11.99	10.29
81	M	17	11.87	10.98
82	M	50	11.92	10.38
83	M	44	11.85	10.99
84	M	17	11.71	10.67
85	M	50	11.58	10.78
86	M	35	12.10	11.55
87	M	35	12.69	11.89
88	M	20	11.01	10.01
89	M	30	12.69	11.10
90	M	50	12.10	11.32
91	M	25	11.58	10.51
92	M	47	11.71	10.33

93	M	49	11.85	11.23
94	M	27	12.61	11.87
95	M	26	12.09	11.45
96	M	30	11.57	11.01
97	M	50	11.79	10.22
98	M	33	11.85	10.45
99	M	49	11.71	10.07
100	M	47	11.69	11.02
101	M	46	11.81	10.34
102	M	49	12.22	11.58
103	M	50	12.21	11.88
104	M	19	12.65	11.78
105	M	17	12.11	11.99
106	M	19	11.98	10.98
107	M	20	11.32	10.95
108	M	40	12.21	11.03
109	M	45	12.55	11.45
110	M	33	11.75	10.56
111	M	19	12.32	11.34
112	M	29	12.55	11.55
113	M	45	11.76	10.87
114	M	50	11.32	10.78
115	M	50	11.67	10.61
116	M	30	12.21	11.94
117	M	29	11.99	11.59
118	M	45	11.83	10.09
119	M	28	11.99	11.49
120	M	19	12.37	11.79
121	M	30	11.75	11.87
122	M	27	11.77	11.05
123	M	30	10.95	10.12
124	M	49	11.98	11.06

125	M	48	11.71	10.55
126	M	44	11.58	11.34
127	M	38	12.10	11.49
128	M	23	12.69	11.75
129	M	45	12.51	11.49
130	M	50	12.12	11.77
131	M	17	11.61	10.57
132	M	50	11.68	10.89
133	M	27	11.71	10.99
134	M	46	11.61	10.77
135	M	36	11.45	10.57
136	M	29	12.64	11.78
137	M	39	12.23	11.75
138	M	50	11.61	10.61
139	M	23	11.81	10.77
140	M	21	11.93	11.31
141	M	32	11.75	10.76
142	M	43	11.99	11.44
143	M	50	10.99	9.89
144	M	23	10.79	10.13
145	M	41	11.86	10.76
146	M	31	11.69	10.75
147	M	21	11.61	10.45
148	M	50	12.87	11.04
149	M	48	12.69	11.12
150	M	50	12.77	11.06

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Female				
cast	**sex**	**age**	**MBDL diameter**	**MLDB diameter**
1	F	18	9.89	9.72
2	F	23	9.52	9.34
3	F	45	10.94	10.12
4	F	28	8.90	8.22
5	F	43	9.76	9.65
6	F	36	9.13	8.58
7	F	29	8.67	8.45
8	F	50	9.56	9.14
9	F	33	9.64	9.56
10	F	28	8.75	8.49
11	F	35	9.31	8.95
12	F	42	10.15	10.21
13	F	19	9.65	8.67
14	F	30	8.34	8.25
15	F	37	9.22	8.74
16	F	45	9.89	9.72
17	F	26	10.12	9.34
18	F	39	10.04	9.12
19	F	47	9.90	9.87
20	F	25	9.76	9.65
21	F	23	9.13	8.98
22	F	46	8.67	8.45
23	F	27	9.56	9.34
24	F	48	9.84	9.76
25	F	39	8.95	8.89
26	F	40	9.01	8.95
27	F	34	10.15	10.10
28	F	29	9.65	8.97

29	F	32	8.64	9.45
30	F	45	9.82	9.74
31	F	37	9.89	9.72
32	F	19	10.12	9.94
33	F	22	9.72	9.64
34	F	37	10.15	9.92
35	F	43	10.07	9.96
36	F	27	9.41	9.33
37	F	39	8.51	8.45
38	F	29	9.84	9.72
39	F	46	9.32	9.19
40	F	36	8.21	8.18
41	F	47	9.57	9.45
42	F	23	9.78	9.37
43	F	31	8.29	8.11
44	F	48	9.95	9.87
45	F	29	9.24	9.11
46	F	41	8.22	8.14
47	F	36	10.15	9.92
48	F	42	10.17	10.06
49	F	26	9.41	9.33
50	F	27	9.11	8.45
51	F	43	10.24	10.14
52	F	23	9.32	9.19
53	F	28	8.91	8.86
54	F	43	9.17	9.05
55	F	26	9.78	9.37
56	F	45	8.29	8.11
57	F	38	8.55	9.37
58	F	45	9.94	9.81
59	F	23	9.22	8.94
60	F	18	10.15	9.97

61	F	27	10.07	10.00
62	F	17	9.41	9.33
63	F	22	8.61	8.45
64	F	23	10.34	10.22
65	F	33	9.32	9.19
66	F	49	8.91	8.78
67	F	50	9.17	9.45
68	F	43	9.78	9.37
69	F	17	8.29	8.11
70	F	36	9.55	9.47
71	F	32	9.94	9.81
72	F	48	9.22	8.74
73	F	39	9.35	9.22
74	F	29	10.27	10.06
75	F	47	9.01	8.93
76	F	24	8.45	8.11
77	F	43	9.84	9.22
78	F	23	9.32	9.19
79	F	19	8.21	8.18
80	F	24	9.47	9.35
81	F	42	9.78	9.37
82	F	26	8.29	8.11
83	F	27	9.95	9.87
84	F	34	9.94	9.81
85	F	50	8.41	8.34
86	F	44	8.76	8.66
87	F	29	8.45	8.31
88	F	17	8.97	8.76
89	F	20	8.45	8.65
90	F	32	8.44	8.23
91	F	34	9.12	8.99
92	F	50	8.33	8.53

93	F	43	8.63	8.25
94	F	17	8.41	8.12
95	F	36	8.65	8.44
96	F	50	8.36	8.15
97	F	27	9.26	9.11
98	F	49	9.77	9.44
99	F	35	9.23	9.17
100	F	18	9.98	9.91
101	F	37	8.45	8.34
102	F	47	8.66	8.43
103	F	43	8.41	8.31
104	F	46	9.58	9.45
105	F	39	9.94	9.81
106	F	45	8.41	8.34
107	F	17	8.66	8.36
108	F	32	8.35	8.21
109	F	18	8.67	8.56
110	F	22	8.45	8.25
111	F	25	8.34	8.23
112	F	37	8.92	8.79
113	F	49	8.53	8.43
114	F	25	8.33	8.25
115	F	35	8.31	8.12
116	F	24	8.55	8.44
117	F	17	8.26	8.15
118	F	21	9.86	9.71
119	F	18	8.84	8.77
120	F	42	9.83	9.67
121	F	50	9.38	9.11
122	F	43	8.45	8.34
123	F	22	8.63	8.56
124	F	48	8.31	8.11

125	F	35	9.88	9.58
126	F	32	9.94	9.81
127	F	26	8.41	8.34
128	F	47	8.66	8.56
129	F	17	8.45	8.31
130	F	36	8.87	8.76
131	F	22	8.45	8.34
132	F	48	8.24	8.13
133	F	21	8.92	8.89
134	F	34	8.43	8.35
135	F	35	8.23	8.15
136	F	47	8.11	8.02
137	F	50	8.35	8.24
138	F	43	8.16	8.05
139	F	36	9.76	9.61
140	F	17	8.74	8.37
141	F	27	9.83	9.77
142	F	33	10.10	9.98
143	F	29	8.45	8.34
144	F	19	8.63	8.36
145	F	49	8.31	8.11
146	F	18	9.88	9.48
147	F	28	10.04	9.91
148	F	33	8.41	8.34
149	F	50	8.66	8.36
150	F	23	8.25	8.11

Appendix 3

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
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12 November 2019

Dr S Bashir Yousif Abdelrahim
Faculty of Dentistry

Ethics Reference Number: BM17/7/12

Project Title: Sex estimation using diagonal diameter measurements of first molars in a Sudanese population.

Approval Period: 25 August 2017 – 25 August 2018

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

BMREC REGISTRATION NUMBER - 130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.