The Inter-Canine Distance in the Maxilla and Mandible for Sex Determination in a Sample of Adults from Khartoum Teaching Dental Hospital, Sudan

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A mini-thesis submitted in partial fulfilment of the requirements for the Degree of Master of Science in the Department of Maxillofacial and Oral Pathology and Forensic Sciences, Faculty of Dentistry, University of the Western Cape

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ABSTRACT

Introduction: In forensic odontology, sex determination is one of the key parameters and is a crucial element in identification of a deceased individual by a forensic investigator. Canines are considered an excellent tool to distinguish gender. This study investigated sexual dimorphism using quantities of the inter-canine distance of the mandibular and maxillary permanent canines in a sample of the Sudanese population living in Khartoum.

Methods: This study was carried out from October to December 2021 at Khartoum Teaching Dental Hospital, Sudan. This study was accomplished on 200 participants (100 females, 100 males) ranging between 19 to 51 years. Measurements of the maxillary and mandibular inter-canine distances were taken using a digital caliper intraorally. Out of these measurements, a percentage of sexual dimorphism was calculated. The data was statistically analyzed by the Student's t-test and results obtained were analyzed.

Results: The analysis concluded the mean inter-canine distance of the mandible was 28.47 ± 4.19 mm on males and 27.26 ± 2.98 mm on females and results of the maxillary inter-canine distance was 32.92 ± 2.50 mm on males and 31.19 ± 2.53 mm on females. The means of the mandibular and maxillary inter-canine distance for males were higher than those of females with a significantly high difference (*P. < 0.000*). The percentages of sexual dimorphism were considerably higher in the inter-canine distance in both the mandible and maxilla (5.5% and 4.4%, respectively) in accordance with the gender difference.

Conclusion: The present study investigated gender in the Sudanese population using maxillary and mandibular inter-canine dimensions. Measuring the inter-canine distance of the mandible is a fast and simple technique to identify gender and is a valuable tool in forensic odontology.

Keywords:

Canines; Dental identification; Forensic odontology; Mandibular inter-canine distance; Sexual Dimorphism; Sudanese Sample; and Maxillary inter-canine distance**.**

DECLARATION

I state that "The inter-canine distance in the maxilla and mandible for sex determination in a sample of adults from Khartoum Teaching Dental Hospital, Sudan" is my original research and was not yield for any other grade nor examination to other universities. Also all sources quoted or used were acknowledged and indicated by complete references.

Mohanad Elhag **August 2021**

Signed.....

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I am utterly in gratitude to all people who helped, guided and gave me their precious time, as, without them, this thesis wouldn't be completed. To my Supervisor: Dr. Susan Chandler and Co-supervisor: Prof. Manogari Chetty.

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Chapter one

Introduction

Forensic odontology deals with legal proceedings in the context of dental applications (Abdullah, 1998). Therefore, the odontometric analysis of human teeth is very important in forensic studies (Kapila *et al.,* 2011).

The overlap of legal and dental professions constitutes forensic dentistry. Forensic dentistry is a part of science that is concerned with the relationship of jaws with teeth as evidence in justice and in law. Some of the main objectives are identifying individuals and gender determination (Alhaija & Qudeimat, 2003).

The dimensional measurement of teeth, which is a non-invasive and readily applicable technique, is helpful in gender determination. The advantages of using odontometric methods in sex determinations are that they are simple, not costly and does not consume time. Gender determination using dental features is predominantly achieved by comparing tooth dimensions (Peckmann *et al.,* 2016).

Research proved that anatomical components of the oral cavity differs from person to person, much like finger prints. This means that dental measurements are distinctive and can be utilized for gender identification. In the past, odontometric studies were used in the process of human identification, which included both the sex and the age of the individual (Reddy *et al.,* 2008; Gorea and Sharma, 2010).

Sexual dimorphism can be defined as the difference between females and males on the foundation of morphological characteristics. Tooth size evaluation, which is a trait of sexual dimorphism in numerous populations, is applicable in forensic investigations. Females have narrower teeth crowns in comparison to males. Sex can be determined via measurements of the inter-canine distance and mandibular canines in cases where there is fragmentation or unavailability of the postcranial bones. Therefore, in catastrophic cases, usage of odontometric techniques is extremely helpful (Almquist, 1974).

Despite the fact that the level of sexual dimorphism varies in different populations, the sexual variation that can be found within the human dentition remains crucial in forensic investigations (Kapila *et al.,* 2011).

Canines have continuously shown the highest degree of sexual dimorphism. As a result, it was proposed that only canines be used for gender determination (Acharya & Mainali, 2009).

Measurements that were used in previous studies in the process of gender identification include the mesio-distal width of the canine, the canine mandibular index and the inter-canine width (Reddy *et al.,* 2008; Gorea & Sharma, 2010).

Looking at all teeth in the human dentition, canines are regarded as the least commonly extracted teeth. This is mainly attributed to the relatively decreased incidence of periodontal disease and dental caries that affect canines. Canines have a mean age of eruption of about 10.87 years and are regarded as the "key teeth" in the process of individual identification (Latif *et al.,* 2016).

It was found that the mandibular canines exhibit the greatest degree of sexual dimorphism of all the teeth, most likely as a result of the following:

1) The exposure of canines to calculus and plaque is less; 2) Canines are less affected by periodontal disease; 3) Mandibular canines show lower degree of pathological migration than some of the other teeth; 4) They are extracted lastly with respect to age; and 5) The probability of canines to survive conditions such as air disasters and hurricanes is more (Kaushal *et al.*, 2003).

For the reasons mentioned above both mandibular canines are considered to exhibit the highest dimorphism of all teeth.

1.1 Problem statement

Sex determination is a key factor in human remains identification. In many situations, for example, mass disasters and aeroplane crashes, the typical methods of identification like fingerprints and photo identification cannot be used. Forensic Anthropologists can use different skeletal assessments to determine sex. The shape of the pelvis or measurements of the skull and long bones are frequently used to estimate sex. However, many of these parts of the skeleton may be absent or damaged as a result of trauma,

bad preservation or other causes. Forensic dentists may act as assistants to other experienced professionals in identifying the gender of remains using teeth.

It should be possible to decide whether the victim is of female or male origin without the use of DNA analysis in cases where tooth-remains are available. DNA analysis is the most reliable method of identification but it is not applicable in all situations due to the state of contamination or decomposition. In addition, it is also known to be the most expensive and time-consuming method.

1.2 Rationale

The main rationale for using teeth in medico-legal cases is the fact that they are the strongest part of the human body. Therefore, they are resistant against numerous types of injuries that may occur in mass disasters. This means that teeth are considered a very helpful tool in forensic studies.

Very few odontometric studies have been established in Sudan. The current study established the effect of the 'sex factor' on the inter-canine distance of the mandibular and maxillary arch in Sudan. This study is the first of its kind in Sudan which determined sex using the lower and upper canines.

Teeth in forensic dentistry constitute a crucial element in recognition of deceased individuals where bodies are unrecognizable for reasons like decomposition, fire or skeletonization. The superiority of gender identification through teeth over DNA analysis is its simplicity and the fact that contamination is not a factor. This means that although DNA analysis is the most accurate method for sex determination, gender identification through teeth analysis are sometimes the better option.

Sexual variation in dental measurements have been well recorded among various nations and populations (Rao and Kiran, 2016; Mohsenpour *et al.*, 2017; Awwad, 2020). Nevertheless, in the Sudanese population, no reference studies of odontometric data is available, which constitutes the focus of the current study.

1.3 Research questions

1. Is there a difference between females and males in inter-canine width?
2. Investigation of sexual dimorphism was conducted using several methods. One of these is the odontometric analysis of maxillary and mandibular canines. The research question is: What is the percentage of sexual dimorphism of mandibular and maxillary inter-canine distance in accordance with gender difference?

Chapter two

Literature review

2.1 Sex identification significance

The importance of human identification is enshrined in the United Nations (UN) Declaration of Human Rights; each free individual has the full right to be recognized and identified after passing away (Zandy, 2019). In the process of human identification, sexuality, i.e. male or female, has been one of the prominent areas that have been extensively studied (Kalia, 2006). In forensic dentistry, the process of human identification, especially using dental features, has been well reported (Pretty and Sweet, 2001). The purpose of using forensic dentistry in human identification varies in legal and disaster management (Pretty & Sweet, 2001; Bakkannavar *et al.,* 2015). In Sudan, the inter-canine distance for males was greater than in females (EL-Shiekh *et al*. 2010). There are two main categories of dental identification; ante mortem and postmortem. These two categories are often adopted to determine specific characteristics of human dental features (Pretty & Sweet, 2001).

The concept of dental dimorphism refers to the process of unique differences in the overall dental characteristics among individuals of different gender, including the size, shape and appearance of the dental features (Parikh & Vyas, 2013). Sexuality in dimorphism refers to morphological dental characteristics that differentiate genders; i.e., male from female (Vishwakarma & Guha, 2011; Grewal *et al.,* 2017).

The self-preservation properties of the teeth also imply that adoption of teeth morphological differences aid in identifying sex through dental remains (Parikh & Vyas, 2013).

Measurements and study of tooth size in many species are acknowledged to show sexual dimorphism (Grewal *et al.,* 2017). The availability and accessibility of teeth for investigation render them an outstanding criminological and archaeological modality for gender discrimination. This presented an advantage over fingerprints, as identification can be performed on severely burned remains, for instance, in terrorist attacks (Kapila *et al.,* 2011).

2.2 Sex determination methods

Methods used for sex determination in Forensic odontology are classified as: 1) Visual technique or clinical aid; 2) Microscopic techniques using Barr bodies and 3) Advanced methods using polymerase chain reaction (Nagare *et al.,* 2018).

2.3 Visual/clinical methods

2.3.1 Sex differences in tooth size

Male teeth in both arches varies in size from female teeth (Richardson & Malhotra, 1975). Similarities of tooth morphology are apparent in males and females unlike teeth sizes which exhibit differences (Sonika *et al.,* 2011).

Generally, males' dental features exhibit bigger tooth measurements than females (Grewal *et al.,* 2017). These unique dental dimensions have been used to determine the sexual orientation of individuals. Different dental guides namely the lower canine index, crown index and incisor index where developed in odontometric studies used in the identification of males and females (Kaleelullah & Hamid, 2020).

The mesio-distal width of canines and incisors together exhibited superior precision in determining between females and males according to a research conducted by Howe *et al.,* (1983). Sex identification can be done by measuring the meiso-distal (m – d) and bucco-lingual dimensions of teeth. That is of great significance in youngsters where their skeletal secondary sexual characteristics have not yet developed. Tooth crown dimensions of both permanent and deciduous teeth amongst females and males show notable differences according to researches. Mandibular canines are more substantial in males than in females with greater dimensional distinctions. Remarkable differences are also noted in premolars, first and second molars and maxillary incisors (Sherfudhin *et al.,* 1996).

2.3.2 Sexual Dimorphism of the Canine

Mandibular canines are characterized by having late eruption, as well as the last to shed according to age. In addition, amongst all teeth they are the least affected by periodontal diseases thus, having a higher degree of dimorphism (Agrawal *et al.,* 2015). In dental anatomy, the canines have been reported to possess the highest probability of sexual dimorphism and is key in identification (Bakkannavar *et al.,* 2015).

In forensic odontology, permanent canines and their arch width (distance between canine tips) aid in gender identification via sexual dimorphism. Canine teeth measurements were studied through various techniques, for instance Moire topography (Suzuki *et al.,* 1984); Fourier analysis (Minzuno, 1990); measurements of linear dimensions such as bucco-lingual width, and inciso-cervical height and the mesial-distal width (Anderson and Thompson, 1973; Rao *et al.,* 1989). A study by Anderson and Thompson (1973) showed that lower inter-canine distance and canine width were higher in males than in females leading to 74% accurate sex determination.

Moreover, sexual dimorphism of the mandibular canine was more prominent than in the maxillary canine. Nevertheless, other researchers (Kuwano, 1983; Minzuno, 1990) stated that, in Japanese population, the maxillary canine showed a higher degree of sexual morphism as opt to the mandibular canine. That is to say, the degree of morphism between the maxillary and mandibular canines in various ethnic groups remains controversial. The mesial-distal width of mandibular canines was tremendously great in males than in females as reported by Rao *et al.,* (1989). Sherfudhin *et al.,* (1996) investigated Indian subjects for the occurrence of canine tooth dimorphism and compared the use of two statistical methods of evaluation. The results concluded a noteworthy dimorphism of the maxillary and mandibular canine teeth. Another study, Işcan and Kedici, (2003) indicated that 77% of sex can be determined using maxillary and mandibular canines and mandibular second molars.

Kieser *et al.*, (1983) executed a canonical discriminant analysis to check anterior and posterior teeth and reflected notable differences in all the studied cases. Consequently, results concluded that second molars, maxillary canines, the bucco-lingual measurements of the first premolar and the mesio-distal dimension of mandibular canines showed more sexually dimorphic, thus gender rates ranges from 70.9% to 93.3%.

In another study, Hashim and Murshid (1993), examined 720 teeth of the Saudi population indicating that the canines were the only teeth with sexual morphism.

In North India, Kaushal *et al.,* (2003) examined 60 individuals and the results exhibited mandibular canines with significant sexual dimorphism.

In another study, using a Nepalese population, Acharya and Maniali (2007) said canines were ranked most significant univariate gender measure, seconded by first and second molars. The greatest sexual dimorphism in mandibular canines was recorded from two huge samples from Malaysia and India. These studies were performed by Angadi *et al.*, (2013) and Khamis *et al.,* (2014). Mustafa and Abuaffan (2021) in Sudan also found maxillary mean values for males were 27.10 mm, and females: 25.45 mm, while the mandibular mean values for males were 20.53 mm, and females:19.76 mm.

2.3.3 Dental index

Tooth proportions were proposed in the identification of genders in addition to absolute tooth size. Rao *et al.,* (1989) suggested the "mandibular canine index" to attribute in identification of sex in an Indian population. Through the mandibular canine mesial-distal dimension researchers acquired the formula: ([Mean mesial-distal canine dimension + [mean mesial-distal canine dimension in female + standard deviation (SD)] in males – SD])/2. The result was 7.1, i.e., 7.1 mm being the greatest mesial-distal measurements of mandibular canines in females while in males' similar dimension is greater. Almost 89% success rate in gender determination resulted from utilizing the above formula (Anderson & Thompson, 1973).

2.3.4 Odontometric differences

The greater gene expression in males results in the odontometric differences between females and males (Işcan & Kedici, 2003). Işcan and Kedici (2003) kept in mind that an overlap exists between female and male tooth measurements resulting in precise diagnosis of sex to be challenging for experienced dentists. It was clear that success was higher with the usage of all available teeth.

2.4 Microscopic methods using Barr bodies

A latent cell containing X and Y chromosomes can aid to identify sex. Buccal smears, blood, biopsy, cartilage, tooth pulp, skin and hair root sheath are all examples that can be studied to check the presence or absence of X chromosomes. Factors such as humidity and the surrounding temperature determine its longevity. Barr body is the first known name of X chromatin and intra-nuclear structures named after its discoverer Barr *et al.*, (1950). Barr body is a mass found in females against the nuclear membranes (Barr *et al.*, 1950). A study executed by Das *et al.*, (2004) concluded that depending on factors such as temperature and humidity, X and Y chromosomes can accurately determine the gender of an individual up to 4 weeks after death. Whittaker *et al.*, (1975) claimed that quinacrine mustard stained on necrotic pulp with the help of fluorescent Y chromosome test for maleness. They also stated that gender identification could be executed 5 weeks after death with utmost precision. According to Duffy *et al.*, (1991) dehydrated pulp tissue can retain Barr bodies and F Bodies Y chromosome. They also claim that with a heat of 100°C for 1 h pulp tissue can preserve their gender diagnostic features.

2.5 Advanced methods using polymerase chain reaction for X and Y chromosomes

Magnifying few portions of relatively short target sequences of DNA is the process of Polymerase chain reaction (PCR) through thermostable Taq DNA polymerase and sequence-specific oligonucleotide primers (Tsuchimochi *et al.*, 2002).

Teeth may uphold high temperatures and are utilized for individuals' identification in forensic medicine. Identifying an unknown body is not possible in circumstances where information is scarce and where few or no dental records are available. Saliva, buccal

mucous membrane and calculus are usually influenced by temperature unlike the enclosed dental pulp (Hemanth *et al.,* 2008). In a study by Tsuchimochi *et al.,* (2008)

DNA from the dental pulp was extracted using the Chelex method which was amplified with typing at Y chromosomal loci and PCR to conclude that the effect temperature has on the gender identification of the teeth. A study done by Hanaoka and Minaguchi, (1996) was to identify gender from teeth and blood by PCR amplification of alphoid satellite through magnification of Y- specific (172 bp) and X-specific (131 bp) sequences on males and in females X-specific sequences. Ultra sonication and subsequent PCR amplification salvage DNA from teeth and accurately 100% result in sex determination according to Sivagami *et al.,* (2000).

2.6 Sex Estimation and Dental Measurements

2.6.1 Inter-canine distance

The lower and upper inter-canine distance is easy to determine and affordable tools may be used in criminological or archaeological studies to determine gender (Parekh *et al.,* 2012).

Regarding forensic dentistry, the lower canine width, inter-canine width and the ratio between them (mandibular canine index) in combination or separate, were utilized in numerous studies (Kaushal *et al.,* 2003; Boaz & Gupta, 2009; Vishwakarma & Guha, 2011). The mandibular and maxillary inter-canine distance can be of spectacular medico-legal value in determination of sex (Baheti *et al.,* 2014).

The mandibular canines are unique and distinct. They are known to retain the majority of their dental characteristics because they are not easily affected by periodontal diseases (Mahajan *et al.,* 2020). The reason why mandibular canines are more resistant to damage is not known (Anderson *et al.,* 1977).

The previous literature indicated that gender dimorphism was evident in the inter-canine distance of the lower and upper canines (Shankar *et al.,* 2013; Mohsenpour *et al.,* 2017; Mahajan *et al.,* 2020; Awwad, 2020).

A considerable number of studies have reported unique sexual dimorphism in mandibular canines, inter-canine distance, canine width and canine index (Parikh & yas, 2013; Ahmed, 2014; Peckmann *et al.*, 2016; Rajarathnam *et al.*, 2016; Prabhakar & Sivapathasundharam, 2019; Magar *et al.*, 2020).

The data collection procedure and analysis of inter-canine measurement has mostly been quantitative in this approach utilizing the Statistical Package in Social Science (SPSS). Scholarly studies have exclusively used a quantitative analysis method with the data collection design focused on similar indigenous population samples of identical origin (Mohsenpour *et al.*, 2017; Hartomo *et al.*, 2019).

A direct relationship between sex dimorphism and both mandibular and maxillary indices has been established. Inter-canine measurement in gender determination has become a standard approach among identical populations with varying odontology characteristics (Mahajan *et al.*, 2020).

In gender discrepancy studies, the average accuracy values of the maxilla and mandible differ depending on the population and often in geographical locations, with statistical significance (Baheti *et al.*, 2014; Mahajan *et al.*, 2020). Although tribe seems not to be an important factor in the study of odontology and forensic dentistry, especially in the determination of sex, the population selection process has always been people from the same region rather than a dispersed population from different origins (Mohsenpour *et al.*, 2017; Hartomo *et al.*, 2019; Rasidi and Gheena, 2019).

2.6.2 Methods of inter-canine measurement in forensic dentistry

There are two methods of inter-canine measurement; direct (intra-oral) and indirect method (extra-oral). When the direct method is undertaken, a digital caliper is used. An acrylic mold bite is placed in the oral cavity for bite impressions in the case of the indirect method (Mahajan *et al.,* 2020). Barrett *et al.,* (1963) claimed that intra-oral measurements are regarded of little reliability in comparison to measuring teeth through cast impressions. Measurements on dental casts and clinical measurement have no significant distinction according to studies by Kaushal *et al.,* (2003) and Sai Kiran *et al.,* (2014**).**

However, the success of using inter-canine width in forensic dentistry has been described using two key approaches; inclusion and exclusion criteria. For instance, inclusion criteria vary from (a) A healthy good gingiva and periodontium, (b) Caries free canine teeth, (c) Normal overjet and overbite (2-3 mm), (d) Zero spacing or crowding in the anterior teeth, and (e) Class I molar and canine relationship (Vishwakarma & Guha, 2011; Mahajan *et al.,* 2020).

The validation of method selection depends on the prevalence of underlining dental conditions in a population. In most cases, the dimensions of canine teeth are firstly noted before inter-canine distance measurement. There have been comparative studies using maxilla and mandibular inter-canine measurement with selected studies focusing only on mandibular inter-canine measurement (Gowhar *et al.,* 2016).

The use of the mandibular inter-canine distance in gender determination has become a standard recommended forensic dental procedure due to its accuracy (Paramkusam *et al.,* 2014).

Chapter three

Aims, Objectives and hypothesis

3.1Aims:

This research aims to evaluate the level of accuracy in sex determination, utilizing the inter-canine distance measurements (dimensions) in the mandible and maxilla using inter-canine distance measurements on a sample of Sudanese adults (19-51) years.

3.2 The objectives were:

1. To establish whether sexual dimorphism is present by measuring the distance between canines in the mandible.
2. To establish whether sexual dimorphism is present by measuring the distance between canines in the maxilla.
3. To determine the percentage of sexual dimorphism according to the gender difference.

3.3 Hypothesis

The distance between canines differ between females and males. The individual's gender can be determined by measuring the distance between canines in the mandible and maxilla.

Chapter four

Materials and methods

4.1 Study design

This is a quantitative comparative cross-sectional study, which was conducted from October to December 2021 at Khartoum Teaching Dental Hospital, Sudan. The study was initiated after obtaining approval from the research ethics committee of the University of the Western Cape (Appendix 1) and the head of Khartoum Teaching Dental Hospital. Participation in the study was voluntary, informed consent was obtained from all patients and all participants were informed about the study objectives before enrollment in the study (Appendix 2). Patients also signed a consent form for clinical photos to be taken and for the publication of the study (Appendix 3).

4.2 Inclusion criteria

- Age: 19 – 51 years
- No spacing between teeth
- Completely erupted mandibular and maxillary anterior teeth
- No caries, inclination or missing teeth
- No history nor evidence of crowns, restorations nor trauma to the anterior teeth

4.3 Exclusion criteria

- Patients with impacted canines
- Restorations or Interproximal caries
- Missing teeth or supernumerary teeth
- Abnormal size or morphology of teeth
- Measurements of tooth size affected by tooth wearing
- Patients going for or busy with orthodontic treatment
- Patients who completed orthodontic treatment

- Patients out of age range
- Non-Sudanese patients

4.4 Study area

The study was executed at Khartoum Teaching Dental Hospital, Khartoum state, Sudan.

4.5 Study population

Sudanese patients (females and males between the ages of 19 and 51 years), who attended Khartoum Teaching Dental Hospital, were the objects of the study.

4.6 Sample size

The study sample consisted of 200 patients comprising 100 males and 100 females in the age group of 19-51 years. The volunteers were randomly selected from the individuals who attended Khartoum Teaching Dental Hospital. Khartoum Teaching Dental Hospital is a governmental hospital that receive patients from all over Sudan. All the patients were Sudanese and from different Sudanese ethnicity.

4.7 Methodology

4.7.1 Covid-19 precaution

On arrival, all patients were triaged and screened for COVID-19 and their temperatures were taken. A twenty-minute interval was maintained between patients. Patients were permitted into the practice one by one for the measurements and the waiting patients maintained a two-meter distance from each other. Patients' personal belongings were kept in individual bags. Precautions were taken by all the participants. Face masks and gloves were worn by staff at reception and examiners.

4.7.2 Intraoral measurements

This methodology was adjusted from Kaushal *et al.,* (2003). The research technique was to measure the distance between canines in both upper and lower jaws in all participants. Dimensions were taken intra-orally (with the participants seated) by a digital caliper with a resolution of 0.01 mm. Resulting values were in millimeters (mm) which were rounded off to two decimal places.

4.7.3 Inter-canine distance

The mandibular and maxillary Inter-canine distance is deliberated as the linear distance between the cusps of the right and left lower canines, and the right and left upper canines (Rao *et al.*, 1989).

Patients were asked to be seated following sanitization of the chair and other relevant tools after which the examiner measured the inter-canine distance using a digital Vernier micro caliper (NEIKO 01407A electronic digital caliper 0-6 inches) with an accuracy of 0.01 mm. The electronic digital vernier caliper used was calibrated/tested for accuracy (see Figure 1).

The one end of the caliper was placed over the centre of the tip of the canine tooth on the one side of the mouth and another end of the caliper was placed over the centre of the tip of the canine tooth on the opposite side (see Figures 2 and 3).

The readings were performed twice from each subject; lower and upper inter-canine distance, and the readings were taken by two examiners.

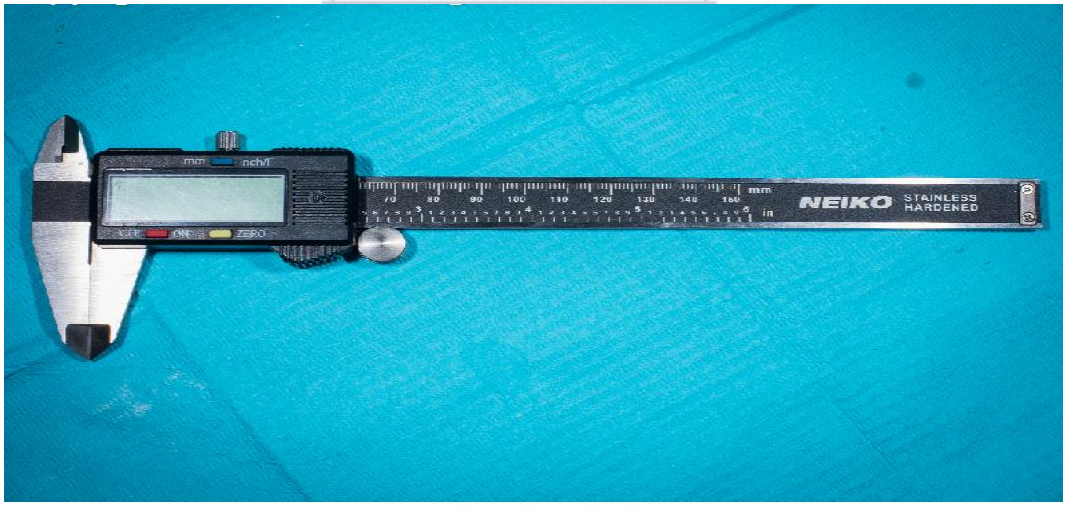

Figure 1: Electronic Digital Vernier caliper

Figure 2: Measurement of Inter-canine distance of Mandibular arch

Figure 3: Measurement of Inter-canine distance of Maxillary arch

4.7.4 Data handling

An Excel Microsoft program was employed to handle the measurements of the data from the digital Vernier caliper and a digital camera was used to document the procedure. The data collected was managed according to the data management plan (Appendix 6).

4.7.5 Inter-Observer reliability

Two examiners took measurements and the average values were taken in case the measurements between the two examiners differed, to minimize random errors.

The first observer was the researcher who conducted the study (see Appendix 7), while the second investigator was a dental surgeon from the Khartoum Teaching Dental Hospital (Appendix 8). The measurements which were obtained by the 'first observer', were repeated blindly by the second observer and compared.

The average measurements (of the first and second examiner) is presented in Appendix 9.

4.8 Data analysis

Statistical analysis was implemented to all collected data using SPSS (IBM Corp, New York Version 22.0) software with the use of Student's *t*-test. It was regarded significant with a p-value of less than 0.05.

In the maxillary and mandibular inter-canine distance descriptive statistics were calculated (range, mean and standard deviation) hence extracting the sexual dimorphism percentage.

Sexual dimorphism was calculated by the formula given by Garn *et al*., (1967) as follows: Sexual dimorphism = (Xm ÷ Xf) -1 × 100, where Xm = Mean of male canine width and Xf = Mean of female canine width.

Chapter five

Results

5.1 Descriptive analysis and frequencies

A sum of 200 patients (100 females and 100 males) ranging in age from 19 to 51 years were included in this study.

The inter-canine distance of the mandible ranged from 21 to 32 mm in females, while it was 21 to 38 mm in males.

On the other hand, the inter-canine distance of the maxillary range was 26 to 37mm in females; while it was 27 to 39 mm in males (see Table 1, Figure 4 and Figure 5).

Table 1: Descriptive analysis of age and inter-canine distance of mandible and maxilla

		N	Mean ± Std. D.	95% C.I. for Mean		Min.	Max.
				Lower Bound	Upper Bound		
Age	**Female**	100	29.18±6.78	27.84	30.52	19.00	45.00
	Male	100	32.92±7.08	31.52	34.32	19.00	51.00
	Total	200	31.05±7.16	30.05	32.05	19.00	51.00
Mandibular inter-canine distance (mm)	**Female**	100	27.26±2.98	26.67	27.85	21.00	32.00
	Male	100	28.47±4.19	27.64	29.30	21.00	38.00
	Total	200	27.87±3.67	27.35	28.38	21.00	38.00
Maxillary inter-canine distance (mm)	**Female**	100	31.19±2.53	30.69	31.69	26.00	37.00
	Male	100	32.92±2.50	32.42	33.42	27.00	39.00
	Total	200	32.06±2.66	31.68	32.43	26.00	39.00

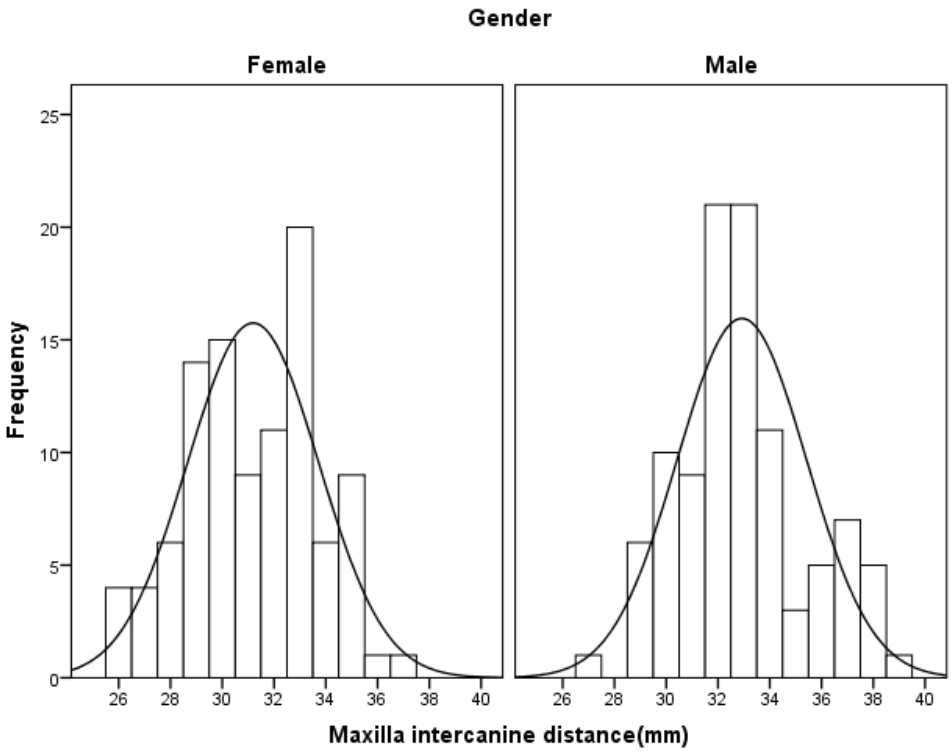

Figure 4: A histogram illustrating frequencies of maxillary inter-canine distance (mm) for males and females

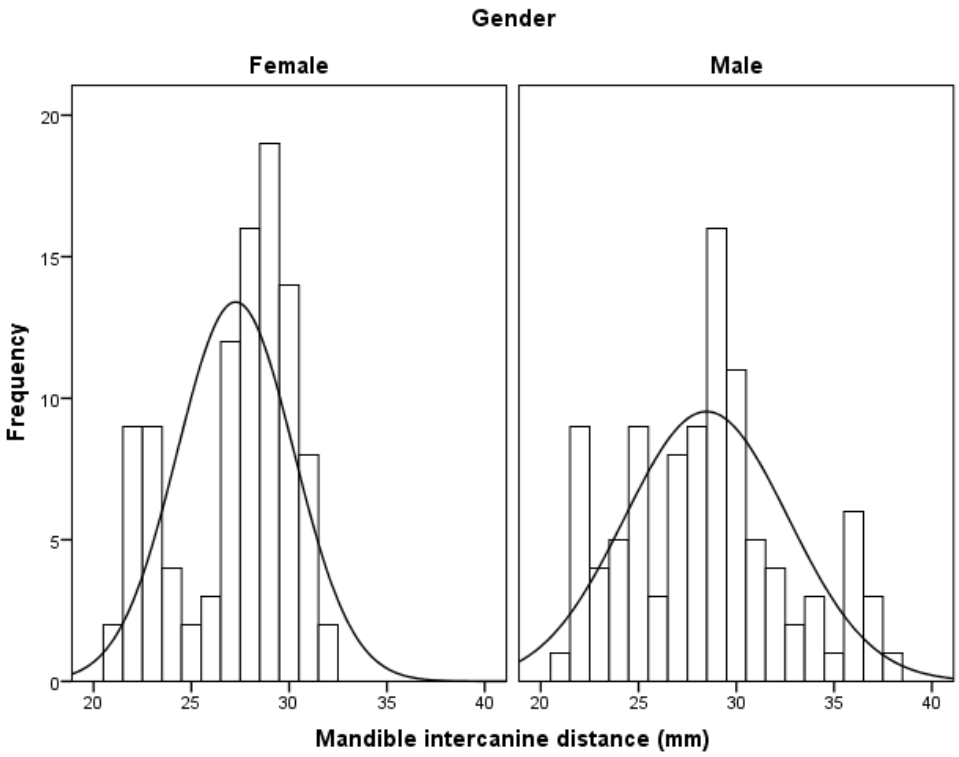

Figure 5: A histogram illustrating frequencies of mandibular inter-canine distance (mm) for males and females

5.2 Inter-canine distance in mandible and maxilla

The means of the inter-canine distance of the mandibles varied significantly (*P. < 0.05*) according to sex as it was higher in males (28.47 ± 4.19 mm) than in females (27.26 ± 2.98 mm). Similarly, the analysis indicated that there was a highly significant difference (*P. < 0.000*) in the means of the maxillary inter-canine distance between males and females, and again it was higher in males, as presented in Table 2, Figure 6 and Figure 7.

Table 2: Mean value comparison of mandibular and maxillary inter-canine according to sex

Measurements		Mean ± Std. D.	t. test (P. value)
Mandibular Inter-canine distance (mm)	**Female**	27.26 ± 2.98	*t.= -2.36 (0.02)*
	Male	28.47 ± 4.19	
Maxillary Inter-canine distance (mm)	**Female**	31.19 ± 2.53	*t.= -4.86 (0.000)*
	Male	32.92 ± 2.50	

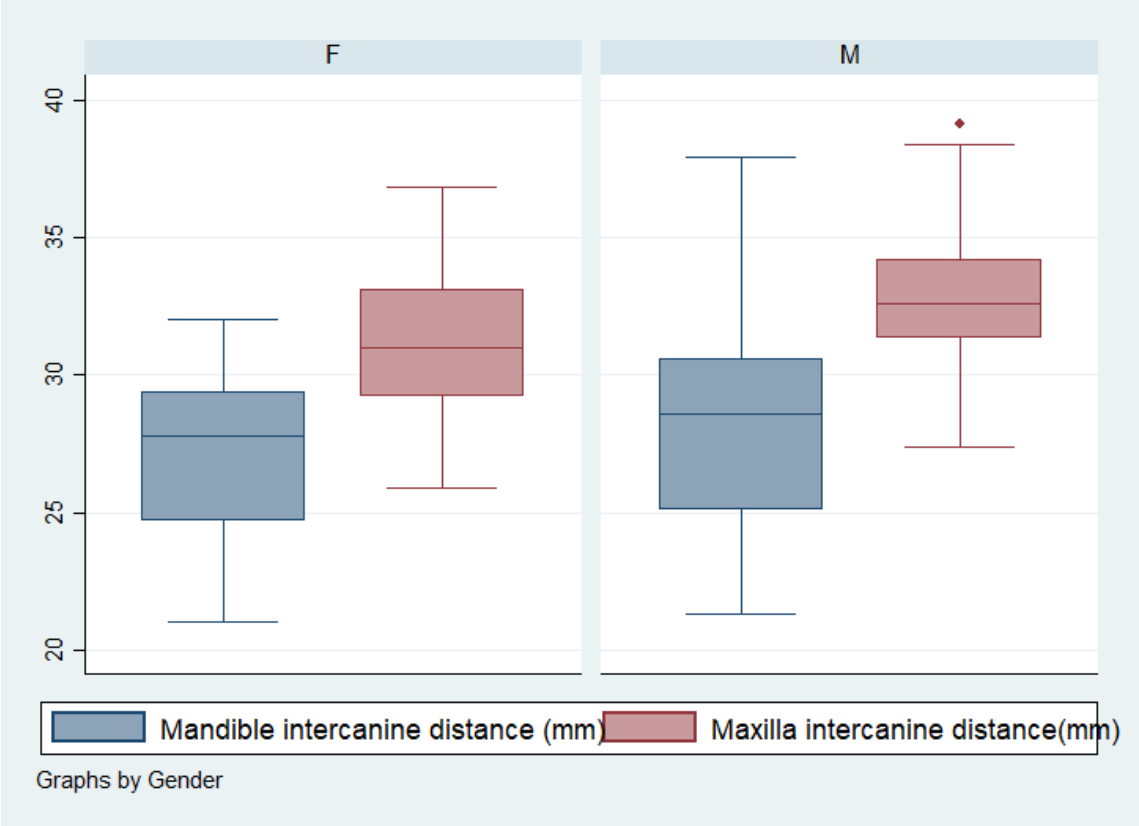

Figure 6: Means of mandibular and maxillary inter-canine distance according to sex

5.3 Sexual dimorphism

The sexual dimorphism of the maxillary and mandibular inter-canine distance was calculated using the formula given by Garn *et al*., (1967), and the results were shown in Table 3. The percentage of sexual dimorphism is the percentage by which the tooth size of males exceeds that of females. The percentages of sexual dimorphism were considerably higher in the maxillary and mandibular inter-canine distances according to gender differences.

Table 3: Sexual dimorphism of maxillary and mandibular inter-canine distance

Measurements	Percentage of sexual dimorphism
Maxillary inter-canine distance	4.44 %
Mandibular inter-canine distance	5.55 %

Chapter six

Discussion

A crucial role in the forensic team is led by a forensic odontologist where dental evidence is vital in the determination of unidentified humans when other methods are of no use. (Al-Rifaly *et al.,* 1997).

Teeth are known for being the most invulnerable and resistant mineralized tissue opposite various agents of destruction. They are beneficial in identification of sex through numerous odontometric techniques, especially during devastating disasters where people are unrecognizable. (Al-Rifaly *et al.,* 1997).

Scientifically, sexual dimorphism is a word used when two genders of the same species exhibit dissimilar characteristics as well as a difference in their sex organs (Prabhakar, 2019).

Dental sex dimorphism has been recorded by many authors in studies of various populations around the world (Pereira *et al.*, 2010; Zorba *et al.*, 2011).

Correct sex determination is a crucial step for forensic purposes (Singh *et al.,* 2012). During this study, an effort was made to ascertain sexual dimorphism by measurement of the inter-canine distance in the maxilla and mandible within the Sudanese population.

Over time, some international researchers have coincided in emphasizing the usefulness of odontometric analysis to estimate human sexual dimorphism. One of the dimensions mostly used was the inter-canine distance (Pereira *et al.*, 2010; Zorba *et al.*, 2011). However, very few odontometric standards exist for the Sudanese to use in forensic sex prediction.

The study was implemented on 200 subjects, of which 100 were females and 100 were males. Our sample size is similar to a study in Iraq that measured the extent of sexual dimorphism in 200 subjects. Previous literature indicated that sexual dimorphism in the maxillary and mandibular canines were evident in its inter-canine distance (Shankar *et al.*, 2013; Mohsenpour *et al.*, 2017; Mahajan *et al.*, 2020; Awwad, 2020)

In the current study, the age range of 19 to 51 years was contemplated, in comparison to another study that had an age range from 21 to 60 years (Sassi *et al.*, 2012).

Several studies have revealed sexual dimorphism using different teeth such as incisors, molars and canines, with different methods and measurements. Based on previous studies, measurement of the canines was the most effective indicator of sexual dimorphism (Ibeachu *et al.,* 2012).

In this study, mandibular canines were selected, since Hashim and Murshid (1993) indicated that the canines were the only teeth that display sexual dimorphism. Other studies by Garn *et al.,* (1967) and Nair *et al.,* (1999) claimed that among all teeth, mandibular canines demonstrated the highest level of sexual dimorphism. Dahberg (1963) considered mandibular canines as the 'key teeth' for personal identification.

The canines are the choice of preference for this study as they were found to be resistant to periodontal diseases and severe trauma. Such characteristics of canine teeth aid in maintaining them through life; hence, making them the last teeth to be lost (Rao *et al.,* 1989).

In this current study, males exhibit a higher inter-canine distance when compared to females with a high significant difference. This is in consensus with other studies (Al-Rifaly *et al.,* 1997; Srivastava, 2010; Magar *et al.,* 2011) while disagreeing with certain other studies (Vishwakarma & Guha, 2011; Hosmani *et al.,* 2013).

Omar and Azab (2009) indicated that among both genders the inter- canine distance is of statistical significance. The mandibular and maxillary inter-canine distance is of great sensitivity in gender identification according to Vyas *et al.,* 2013. Another study conducted by Abdullah, (1998) concluded that in males the inter-canine distances of the mandibular and the maxillary dental arches are significantly high in comparison to females in Saudi population.

A study from Sudan, to investigate the relationship between the intercanthal distance and the anterior maxillary tooth size in the Sudanese population, showed that the

measurements of inter-canine distance were found greater in males than in females (EL-Sheikh *et al.*, 2010).

Conversely to this study, a group of Egyptian adults exhibited no statistical significant differences between females and males inter-canine distance as claimed by Kaddah (1998).

Diversity exists in the dental arch characteristics and measurements of various nations and ethnicities (Carter & McNamara, 1998). Garn *et al.*, (1966) examined sexual dimorphism through calculating the mesiodistal width of canine teeth in various ethnicities. They concluded that the mandibular canine demonstrated a higher degree of sexual dimorphism than in the maxillary canine. However, Minzuno (1990) reported that, the maxillary canine showed a higher degree of sexual dimorphism compared to the mandibular canine in the Japanese population. Consequently, the degree of sexual dimorphism between the mandibular and maxillary canines in various ethnic groups remains debatable.

Therefore, variations in ethnic groups of multiple study populations can partly justify the ranges in the inter-canine distance results obtained.

The current study emphasized that the differences in the inter-canine distance, both in the maxilla and the mandible in males and females, were highly significant (p-value <0.01). This is attributed to the fact that the size of the basal bone is mirrored in the width of the dental arch and because males in particular possess larger basal bones than females (Hussein *et al.*, 2009).

It was observed that the mean mandibular inter-canine distance in males was 28.47 ± 4.19 mm and the value in females was 27.26 ± 2.98 mm. Similar results have been observed by Al-Rifaiy *et al.*, (1997) in Saudi Arabia males: 27.01 ± 2.31 mm and females: 26.46 ± 2.77 mm, Ahmed (2014) in Iraq males: 27.61 ± 2.25 mm, females: 26.55 ± 2.30 mm, George *et al.*, (2014) in Egypt males: 32.11 ± 1.186 mm, females: 30.88 ± 1.150 mm, Mohsenpour *et al.*, (2017) in Iran males: 28.4 ± 1.73 mm, females: 26.34 ± 1.4 mm, Awwad (2020) in Egypt males: 27.59 ± 2.04 mm, females: 26.08 ± 1.69 mm, Mustafa and Abuaffan (2021) in Sudan with smaller mean values compared to our results, males: 20.53 ± 3.04 mm, females: 19.76 ± 1.36 mm.

However, the results of the current study contradicted those of Rao *et al.*, (2016) in which statistical insignificance was found in the mean mandibular inter-canine distance between females and males (males: 26.77 ± 1.45 mm, females: 26.43 ± 1.60 mm) and Alanazi *et al.*, (2022) (males: 26.39 ± 2.62 mm, females: 26.38 ± 2.31 mm).

The findings of this study showed that the maxillary inter-canine distance range was 26 to 39 mm, which contradicted another study from Sudan which revealed the range from 30 to 45 mm (EL-Sheikh *et al.*, 2010).

In the results of the present study, the mean inter-canine distance for the maxilla was found to be highly significant 32.92 ± 2.50 mm in males and 31.19 ± 2.53 mm in females. Those findings are similar to other studies conducted by EL-Sheikh *et al.*, (2010) in Sudan with higher mean values compared to our values: males: 37.1 and in females: 35.19 mm, Baheti *et al.*, (2014) in India males: 36.11 ± 1.41 mm, in females: 34.78 ± 1.78 mm, Mohsenpour *et al.*, (2017) in Iran males: 35.27 ± 1.56 mm, females: 34.20 ± 1.08 mm, Awwad (2020) in Egypt males: 34.50 ± 2.41 mm, females: 32.55 ± 2.56 mm, Mustafa and Abuaffan (2021) in Sudan with smaller mean values compared to our results, males: 27.10 mm, and in females: 25.45 mm.

The variations in the means of maxillary and mandibular inter-canine values between the researchers may probably be due to ethnic variations; various instruments were applied for measuring; and distinct ways of taking measurements, for example. intra-orally or extra-orally, using casts.

In the current study, the percentages of sexual dimorphism were considerably high in the inter-canine distance in both the mandible and maxilla (5.5% and 4.4%, respectively) according to the gender difference. These findings coincide with those of Ahmed (2014) and Baheti *et al.*, (2014).

The study limitations

Limitations of this study included the fact that the study was narrowed to the percentages and the statistics of sexual dimorphism confined to the Sudanese population living in Khartoum.

Also, this study was limited by the small sample size which was from one state only. Even though the sample size was of adequate size, further future studies should be conducted to include different ethnicities of the Sudanese adults.

Sex assessment is best accomplished by measurements of all teeth available rather than the indices of individual teeth even though, canines exhibited the utmost and ultimate consistency of sexual dimorphism.

These measures are not beneficial in patients with missing canines. Hence, the intermolar arch width and the meiso-distal width of molars can be utilized for gender identification. One of the limitations of the present study was that the inter-molar arch width was not measured because dental casts (extra-oral) were not used, which may be a better assessment method to establish gender accurately.

This study used an intra-oral technique due to facing certain obstacles in using extra-oral methods. Hence, additional studies are required using both methods.

Chapter seven

Conclusion & Recommendation

Conclusion

In essence, the inter-canine distance of the mandible and the maxilla was found to be higher in the males than the females and the difference was highly significant statistically. In addition, the percentages of sexual dimorphism were considerably high in inter-canine distances in both the maxilla and mandible according to gender differences.

The current study investigated the sex assessment in a Sudanese population using maxillary and mandibular inter-canine dimensions. The mandibular inter-canine distance is a fast and simple technique for determining sex and it is a valuable tool in forensic odontology.

Finally, the results reflected that this technique can be used in forensic odontology in Sudan, as a supplementary tool in human identification.

Recommendation

Cultural, racial and environmental factors are known to shape the tooth morphology, therefore more studies on diverse nations will be beneficial to establish dental morphometric measurements databases. Consequently, different variations will surface among populations to benefit genetic, legal, anthropologic and forensic applications. Intra-oral measurements must be compared with measurements of dental casts (extra-oral).

The study must be repeated in other regions in Sudan to increase reliability and additional research is necessary is to be executed on other ethnicities to assert seen observations.

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APPENDIX

APPENDIX 1

UNIVERSITY of the WESTERN CAPE

50 YEARS of hope, action & knowledge

06 April 2021

Dr M Elhag
Oral & Maxillofacial Pathology and Forensics Sciences
Faculty of Dentistry

Ethics Reference Number: BM20/10/25

Project Title: The intercanine distance in the maxilla and mandible for sex determination in a sample of adults from Khartoum teaching dental hospital, Sudan

Approval Period: 01 April 2021 – 01 April 2024

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 annually by 30 November for the duration of the project.

Permission to conduct the study must be submitted to BMREC for record-keeping.

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

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FROM HOPE TO ACTION THROUGH KNOWLEDGE.

APPENDIX 2

UNIVERSITY *of the*
WESTERN CAPE

CONSENT FOR THE PARTICIPATION IN THE

STUDY TITLED: The inter-canine distance in the maxilla and mandible for sex determination in a sample of adults from Khartoum Teaching Dental Hospital, Sudan

1. I have read and comprehended the information sheet regarding this research project. Information has been deliberated to me and any misunderstanding or concerns have been cleared.

Yes……. No…….

2. I fully understand that I do not have to participate in this study and that I can opt-out at any time without giving any reason. In addition, not affecting my future medical and dental care.

Yes……. No…….

3. I am conscious of the possible risks of this project study to me.

Yes……. No…….

4. I permit the researchers to observe medical records for any relevant information while keeping its confidentiality.

Yes……. No…….

5.A copy concerning of the information sheet was handed to me and this completed consent form.

Yes……. No……

Patient Name: ……

Patient signature: ……

To be completed by the Principal Investigator

I, thoroughly deliberated the nature and purpose of this research to the patient mentioned above. Also the risks involved as well as the benefits. I encouraged them to ask any questions regarding the study.

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks involved as well as the possible benefits. I have invited them to ask questions on any aspect of the study that concerned them.

Principal Investigator Name: ……

Qualifications: ……

Signature: ……

Date: ……

APPENDIX 3

UNIVERSITY *of the*
WESTERN CAPE

CONSENT FORM TO TAKE PHOTOGRAPHS AND PUBLISH

STUDY TITLE: The inter-canine distance in the maxilla and mandible for sex determination in a sample of adults from Khartoum Teaching Dental Hospital, Sudan

DONE BY: Dr. Mohanad Bahser Elhag

By signing this form below, I confirm that this consent form has been explained to me in terms that I understand.

I consent for these photographs to be used in this study and medical publications, including medical journals, textbooks, and electronic publications. I understand that the images may be seen by members of the general public, in addition to scientists and medical researchers that regularly use these publications in their professional education. Although these photographs will be used without identifying information such as my name, I understand that it is possible that someone may recognize me. I also agree for my image to be shown for teaching purposes and to be used for my medical record.

Name……

Date……

Signature…….

APPENDIX 4

UNIVERSITY of the
WESTERN CAPE

الموافقة على المشاركة في الدراسة

عنوان الدراسة: المسافة البينية في الفك العلوي والفك السفلي لتحديد الجنس في عينة من البالغين من مستشفى الخرطوم التعليمي لطب الأسنان ، السودان

1. لقد قرأت وفهمت ورقة المعلومات حول هذا المشروع البحثي. تم شرح المعلومات بالكامل لي وتمكنت من طرح الأسئلة ، وقد تم الرد عليها جميعًا بما يرضي. نعم..... لا.....

2. أفهم أنه لا يتعين علي المشاركة في هذه الدراسة وأنه يمكنني إلغاء الاشتراك في أي وقت. أدرك أنه لا يتعين علي تقديم سبب لإلغاء الاشتراك ، وأدرك أن إلغاء الاشتراك لن يؤثر على مستقبلي في الرعاية الطبية ورعاية الأسنان. نعم..... لا.....

3. أنا على دراية بالمخاطر المحتملة لهذه الدراسة البحثية بالنسبة لي. نعم..... لا.....

4. أعطي الإذن للباحثين للنظر في سجلاتي الطبية للحصول على المعلومات. لقد تم التأكيد لي أن المعلومات الخاصة بي ستبقى سرية. نعم..... لا.....

5. لقد تلقيت نسخة من ورقة المعلومات واستمارة الموافقة المكتملة. نعم..... لا.....

اسم المريض: .....

توقيع المريض: .....

APPENDIX 5

UNIVERSITY of the
WESTERN CAPE

استمارة الموافقة على التقاط الصور والنشر

عنوان الدراسة: المسافة البينية في الفك العلوي والفك السفلي لتحديد الجنس في عينة من البالغين من مستشفى الخرطوم التعليمي لطب الأسنان ، السودان

اعداد: د.مهند بشير الحاج

من خلال التوقيع على هذا النموذج أدناه ، أؤكد أنه تم شرح نموذج الموافقة هذا لي بالعبارات التي أفهمها أوافق على استخدام هذه الصور في هذه الدراسة والمنشورات الطبية ، بما في ذلك المجلات الطبية والكتب والمنشورات الإلكترونية. أفهم أن هذه الصور قد يشاهدها عامة الناس ، بالإضافة إلى العلماء والباحثين الطبيين الذين يستخدمون هذه المنشورات بانتظام في تعليمهم المهني. سيتم استخدام هذه الصور بدون معلومات تعريفية مثل اسمي ، إلا أنني أفهم أنه من الممكن أن يتعرف علي شخص ما. أوافق أيضًا على عرض صورتي لأغراض التدريس واستخدامها في سجلي الطبي.

اسم المشارك.....
تاريخ.....
التوقيع.....

APPENDIX 6

DATA MANAGEMENT PLAN (DMP)

Faculty	Dentistry
Department	Department of Oral & Maxillofacial Pathology and Forensic Sciences
Administrative Data	
Project title The Inter-Canine Distance in the Maxilla and Mandible for Sex Determination in a Sample of Adults from Khartoum Teaching Dental Hospital, Sudan	
Registration details (registration number) 3818047	
Funder	self-funded
Grant number N/A	

Abstract - project description (include the research questions)

ABSTRACT

Introduction: Gender determination is one of the important parameters in forensic odontology, and becomes the first priority in the process of identification of a person by a forensic investigator. Canines are considered an excellent tool to distinguish gender. This study investigated sexual dimorphism by measuring the inter-canine distance of the maxillary and mandibular permanent canines in a sample of the Sudanese population living in Khartoum.

Methods: The study will be carried out 2020 at Khartoum Teaching Dental Hospital, Sudan. The study will be conducted on 200 subjects (100 males, 100 females) in the 19 to 51 years' age group. Maxillary and Mandibular inter-canine distance will be measured intra-orally by using a digital caliper from which these measurements, the percentage of sexual dimorphism will be calculated. The data will be a subject to statistical analysis using Student's t-test and the results will be analyzed.

Research questions

3. Is there a difference between males and females in inter-canine width?

4. Investigation of sexual dimorphism was conducted using several methods. One of these is odontometric analysis of maxillary and mandibular canines. The research question is, what is the percentage of sexual dimorphism of maxillary and mandibular inter-canine distance in accordance with gender difference?

Principal Investigator (PI)? Mohanad Basher Ibrahiem Elhag

ORCID (PI)? 0000-0003-2834-8562

Contact details of the PI? hnoobasha@gmail.com +2499979791626

The timeframe of the research project. The research project was started on 06-04-2021 and concluded on 10-05-2022.

Date the DMP was created/submitted? Created Oct 2021 – May 2022

Date /s the DMP was revised? N/A

Data

What will be collected? Describe the data and formats (raw and refined/cleaned data). The study was conducted on 200 subjects (100 males, 100 females) 19 to 51 years' age group. Sudanese nationality Maxillary and Mandibular inter-canine distance were measured intra-orally by using a digital caliper. From these measurements, sexual dimorphism percentage was calculated. The data were statistical analyzed using Student's t-test and the results were examined.
When describing formats, please identify storage requirements by (expected file sizes and quantities). 2 forms were used, one for males and one for females, labelled with a number, gender, age, and inter-canine distance for maxilla and inter-canine distance for maxilla, Excel sheet used. Storage requirement not more than 50GB". Stored on a password-protected computer.
Is your data original or will you reuse existing data (or a combination)? All data are original data.
How will the data be collected? (e.g. interview; questionnaire; observation) Informed consent was obtained from the patient, Patients were asked to be seated following sanitization of chair and other relevant tools after which the examiner measured the inter-canine distance using a digital Vernier caliper with an accuracy of 0.01 mm, one end of the caliper located over the centre of the tip of one side canine tooth and another end of caliper located over the centre of the tip of opposite side canine tooth. Two readings were taken from each subject; mandibular inter-canine distance and maxillary inter-canine distance, PI and the dental specialist (who was 2nd examiner) were calibrated before taking the measurements. PI took 1st reading, Independent specialist took 2nd reading. Reading captured was the average between the two readings.
Which software and version will be used? Windows 11 Home and Microsoft Excel programs were used to handle the measurement data from the digital Vernier caliper and the digital camera used to document the procedure.
Which operating system is used at the time of collecting the data? Microsoft Excel program will handle the measurements data from the digital Vernier caliper and use a digital camera to document the procedure, and all collected data will be statistically analyzed using SPSS (IBM Corp, New York Version 22.0) software by the Student's *t*. test.
Documentation (legislation, policies, and guidelines)
Applicable legislation for legal compliance (e.g. Protection of Personal Information Act - POPIA). All data was captured in accordance with the POPI Act and the Declaration of Helsinki.
Institutional and funder policies. Investigation and analysis were done in accordance with the University of the Western Cape's policies containing principles of The Declaration of Helsinki and the POPIA.
Metadata schema and version used (e.g. Dublin Core) -----
Descriptive document (How the data was analyzed and how it is used. Upload this document with the data onto the repository). The actual data of the patient was only known to the PI. Each participant was given an alphanumeric code, linked to the data of the patient.

Applicable Memorandum of Understanding (MOU) that defines roles and responsibilities for data collection, administration, and sharing. N/A Only informed consent was obtained from the patients, as only the PI and the participant were involved. The data of the participants will not be shared, as participants were made anonymous by giving them the alphanumeric value. When the project is published, only relevant data will be shared (and these numbers if necessary). It will also only be published in an ISI-approved peer-reviewed journal.
Ethical compliance and approval
Have you received ethical approval (attached letter)? Yes, approval was obtained for this study from the research ethics committee of the University of the Western Cape, See Appendix 1.
How will you obtain consent? Participation in the study was voluntary, informed consent was obtained from all patients and all participants were informed about the study objectives before enrollment in the study. Patients also signed a consent form to take clinical photos and to publish the study, see Appendix 2.
How will you handle intellectual property issues? For the time the degree is conducted, it will be the property of the PI. Once the degree has been awarded, it becomes the property of the University of the Western Cape.
How will you manage copyright concerns? Copyrights are not applicable at this point but will be dealt with in accordance with the University of the Western Cape's policies.
How will you manage confidentiality concerns? Informed consent was obtained from all participants. All data was captured in accordance with the POPIA Act. Participants de-identified and made anonymous by giving them an alphanumeric code. Informed consent was also obtained for taking clinical pictures, but the pictures were cropped and only the oral and intra-oral pictures were used.
Secure Storage and Backup
How will the primary (raw) data be securely stored? All data is securely stored on a password-protected computer. The participants de-identified and given an alphanumeric number. The information from the participants will only be known to the PI. Once projects are completed, raw data will be destroyed and only refined data stored.
Where will the refined data be stored? All data is securely stored on a password-protected computer. The participants de-identified and given an alphanumeric number. Once projects are completed, raw data will be destroyed and only refined data stored**.** Back-up will be to the Cloud or Google Drive, with password-only access.
How will you share public data? Once the project is completed, the data will be shared on the University library website. When it is published, only ISI-approved peer review journals will be considered.
How will you address security and backup? The computer used was password protected and the participants were de-identified/anonymized by giving them alphanumeric numbers. Back-up will be to the Cloud or Google Drive, with password-only access.
Data Sharing
Is there any funder or institutional restrictions on sharing the data? No

How will the data be shared? Once the project is completed, the data will be shared on the University library website. When it is published, only ISI-approved peer review journals will be considered.
How will data be securely shared? Participants will be anonymized and given alphanumeric numbers. Thus, the participant's data will only be known to the PI.
Data Selection, Preservation (Archiving), and Retention
Which data will be shared? Data giving the background for the project, literature review, and rationale for why the project was registered will be shared. The data captured during the execution of the project will be shared, with participants being anonymized by giving them alphanumeric numbers. The analysis and discussion of the findings and conclusions obtained from the findings, as well as recommendations for future research in this field, will also be shared.
What is the long-term storage plan? On google drive.
How long is the data expected to be stored? The raw data will be destroyed upon the completion of the project. The refined data will be destroyed after 10 years.
END

APPENDIX 7

Table showing the raw data collected by the first examiner

No.	Gender	Age	Mandibular inter-canine distance (mm)	Maxillary inter-canine distance (mm)
1	F	22	28	33.2
2	F	22	27	33
3	F	32	32	35
4	F	26	26.4	33.1
5	F	29	21.7	30
6	F	26	22	29.3
7	F	36	23.6	29.1
8	F	27	27.3	32.4
9	F	30	22.9	28
10	F	22	21.8	27.3
11	F	26	30.2	35.4
12	F	21	29.1	35.9
13	F	38	23.9	29.7
14	F	28	24.8	29
15	F	31	29.6	34.7
16	F	37	23.4	29.1
17	F	35	21.6	26.4
18	F	28	29	34.2
19	F	23	23.1	29.2
20	F	27	27.3	33.1
21	F	38	23.7	29.7
22	F	31	28.1	33.3
23	F	26	21.7	27
24	F	21	23.4	28.8
25	F	36	27.7	32.3
26	F	28	29.6	34.8
27	F	34	31.1	36.8
28	F	27	26.2	32.6
29	F	22	23.2	28
30	F	20	21	26.3
31	F	31	24.6	29.2
32	F	34	23.2	28.4
33	F	22	21.9	25.9
34	F	24	30.7	35.2
35	F	32	23	28.4
36	F	20	21.7	27.1
37	F	21	21.3	28.7
38	F	32	23.6	29.1
39	F	26	21.7	28.1

40	F	24	26.1	33.1
41	F	21	23.3	29.7
42	F	37	21.8	26.2
43	F	30	23.2	29.8
44	F	27	29.3	33.2
45	F	24	27.7	30.8
46	F	30	30.9	32.9
47	F	28	27.1	29.7
48	F	19	30.7	35.1
49	F	22	27.1	29.9
50	F	24	29.2	30.7
51	F	38	29.3	30.4
52	F	40	28.4	30.9
53	F	44	29.5	33.2
54	F	30	30	33.8
55	F	32	28.7	32.1
56	F	27	27.1	29.2
57	F	24	26.9	28.7
58	F	28	27.4	30.7
59	F	30	28.7	31.8
60	F	22	30.8	32.2
61	F	34	27.7	28.9
62	F	24	27.2	30.2
63	F	27	30.3	32.2
64	F	40	29.4	34.1
65	F	44	28.6	30.7
66	F	45	27.7	29.9
67	F	32	27.6	33.4
68	F	20	29.3	32.9
69	F	25	29.4	32.9
70	F	25	28.9	31.1
71	F	27	28.7	30.1
72	F	30	27.2	29.2
73	F	31	29.3	31.9
74	F	38	27.4	28.4
75	F	29	26.7	27.3
76	F	32	27.5	29.9
77	F	31	30.4	32.2
78	F	40	30.2	31.4
79	F	28	29.1	31.7
80	F	27	27.7	29.2
81	F	22	28.2	33.2
82	F	22	29.4	33
83	F	21	29.9	33

84	F	27	27.8	30.2
85	F	29	27.9	29.8
86	F	40	30.7	34.9
87	F	33	31.8	31.7
88	F	22	29.9	35.1
89	F	39	28.7	33
90	F	43	29.9	32.2
91	F	19	29.3	30.9
92	F	30	29.3	33
93	F	35	28.4	33.2
94	F	39	27.5	30.9
95	F	42	30.9	33.8
96	F	21	30.7	34.7
97	F	23	30	34.2
98	F	45	29.9	32.9
99	F	23	30.3	33.8
100	F	22	27.7	29.9
101	M	31	27	37
102	M	36	24.8	32.6
103	M	20	25	32.2
104	M	19	26.1	27.4
105	M	27	27.1	32.2
106	M	29	28.2	37.2
107	M	30	27.4	34.9
108	M	32	28.7	33.7
109	M	19	24.2	31.9
110	M	29	28.4	30.3
111	M	32	21.8	29.1
112	M	38	23.4	32.7
113	M	31	25.1	31.5
114	M	35	21.7	32.1
115	M	33	24.6	32.6
116	M	31	22.9	31.3
117	M	38	21.4	30.1
118	M	36	22.5	29
119	M	33	23	34.2
120	M	31	24.4	28.9
121	M	34	23.3	31.7
122	M	40	25.1	32.6
123	M	35	23.7	31.8
124	M	37	24.5	33.2
125	M	34	22.4	29.5
126	M	42	22.2	32.7
127	M	34	26	36.1

128	M	33	24.9	32.7
129	M	33	23.8	31.6
130	M	29	25.1	32.4
131	M	28	26.1	34.2
132	M	40	29.1	33.1
133	M	34	27.5	32.3
134	M	40	29.7	31.5
135	M	32	22.4	31.8
136	M	29	28.9	34.8
137	M	41	24.7	33.7
138	M	51	22.4	32.3
139	M	37	22.5	31.4
140	M	22	25.2	31.5
141	M	24	27.9	32.1
142	M	19	29.9	31.7
143	M	36	21.9	33.1
144	M	41	26.9	32.7
145	M	34	27.1	29.5
146	M	36	30.2	33.2
147	M	34	29	31.8
148	M	39	29.1	32.6
149	M	33	28.4	31.7
150	M	30	27.1	28.9
151	M	32	30.2	34.2
152	M	35	27	29
153	M	39	29.1	30.1
154	M	32	28.1	31.3
155	M	34	29	32.6
156	M	36	28.6	31.3
157	M	29	26.9	31.5
158	M	39	27.8	32.7
159	M	33	27.9	29.1
160	M	33	28.6	30.3
161	M	29	29.9	34.5
162	M	30	30.1	35.1
163	M	40	27.4	33.9
164	M	33	36.9	37.1
165	M	27	37.1	38
166	M	40	29	30.9
167	M	44	30.9	33.5
168	M	25	36.4	37.1
169	M	21	30.3	38
170	M	30	30.1	30.9
171	M	40	29.2	33.5

172	M	33	31.9	37.1
173	M	27	28.6	32.9
174	M	20	36.9	37.8
175	M	20	28.9	29.9
176	M	20	35.9	37.7
177	M	41	37.9	39.1
178	M	30	36.2	37.1
179	M	42	32.2	33.3
180	M	48	30.8	32.7
181	M	39	32.7	33.5
182	M	29	33.9	34.4
183	M	22	35.6	35.9
184	M	44	34.5	35.7
185	M	32	34.9	36.6
186	M	29	32.4	33.2
187	M	19	29	30
188	M	32	31.9	33
189	M	40	28.9	29.9
190	M	34	35.9	36.1
191	M	35	30.9	30.9
192	M	20	32.6	33.2
193	M	25	36.1	38.4
194	M	27	30.9	32.5
195	M	40	34.5	36.1
196	M	45	30.4	30.9
197	M	44	29.9	33.2
198	M	49	31.1	32.3
199	M	35	30	30.9
200	M	29	28.9	29.9

APPENDIX 8

Table showing the raw data collected by the second examiner

No.	Gender	Age	Mandibular inter-canine distance (mm)	Maxillary inter-canine distance (mm)
1	F	22	27.9	33.3
2	F	22	27	33
3	F	32	32	35
4	F	26	26.5	33
5	F	29	21.8	30.1
6	F	26	22	29.3
7	F	36	23.6	29.2
8	F	27	27.3	32.4
9	F	30	22.9	28
10	F	22	21.8	27.3
11	F	26	30.2	35.4
12	F	21	29	35.8
13	F	38	23.9	29.8
14	F	28	24.7	28.9
15	F	31	29.6	34.7
16	F	37	23.4	29.1
17	F	35	21.7	26.5
18	F	28	29	34.3
19	F	23	23	29.3
20	F	27	27.3	33.1
21	F	38	23.7	29.7
22	F	31	28.2	33.2
23	F	26	21.7	27
24	F	21	23.4	28.8
25	F	36	27.7	32.3
26	F	28	29.6	34.9
27	F	34	31.1	36.8
28	F	27	26.2	32.6
29	F	22	23.2	28
30	F	20	21	26.3
31	F	31	24.6	29.2
32	F	34	23.2	28.4
33	F	22	21.9	25.9
34	F	24	30.6	35.2
35	F	32	23	28.4
36	F	20	21.7	27.1
37	F	21	21.3	28.7
38	F	32	23.6	29.1
39	F	26	21.6	28.1

40	F	24	26.1	33.1
41	F	21	23.3	29.7
42	F	37	21.8	26.2
43	F	30	23.3	29.9
44	F	27	29.3	33.2
45	F	24	27.7	30.7
46	F	30	30.8	32.8
47	F	28	27.1	29.7
48	F	19	30.7	35.1
49	F	22	27.1	29.9
50	F	24	29.2	30.7
51	F	38	29.3	30.4
52	F	40	28.4	30.9
53	F	44	29.5	33.2
54	F	30	30.1	33.9
55	F	32	28.7	32.1
56	F	27	27.1	29.1
57	F	24	26.8	28.6
58	F	28	27.4	30.7
59	F	30	28.7	31.8
60	F	22	30.8	32.2
61	F	34	27.7	28.9
62	F	24	27.2	30.2
63	F	27	30.3	32.2
64	F	40	29.4	34.1
65	F	44	28.6	30.7
66	F	45	27.7	29.9
67	F	32	27.6	33.3
68	F	20	29.3	32.9
69	F	25	29.3	32.8
70	F	25	28.9	31.1
71	F	27	28.7	30.1
72	F	30	27.3	29.3
73	F	31	29.3	31.9
74	F	38	27.4	28.4
75	F	29	26.7	27.3
76	F	32	27.6	30
77	F	31	30.4	32.2
78	F	40	30.2	31.4
79	F	28	29.1	31.7
80	F	27	27.7	29.2
81	F	22	28.3	33.1
82	F	22	29.4	33
83	F	21	29.9	32.9

84	F	27	27.9	30.3
85	F	29	27.8	29.6
86	F	40	30.8	34.9
87	F	33	31.8	31.7
88	F	22	29.8	35.1
89	F	39	28.7	33
90	F	43	29.9	32.2
91	F	19	29.1	30.9
92	F	30	29.3	33
93	F	35	28.5	33.2
94	F	39	27.5	30.9
95	F	42	30.9	33.8
96	F	21	30.8	34.8
97	F	23	30.1	34.2
98	F	45	29.9	32.9
99	F	23	30.2	33.7
100	F	22	27.7	29.9
101	M	31	27.1	37.1
102	M	36	24.8	32.6
103	M	20	24.9	32.2
104	M	19	26.1	27.4
105	M	27	27	32.1
106	M	29	28.2	37.2
107	M	30	27.4	34.9
108	M	32	28.7	33.7
109	M	19	24.2	31.9
110	M	29	28.5	30.3
111	M	32	21.8	29.1
112	M	38	23.4	32.7
113	M	31	25.1	31.5
114	M	35	21.8	32.1
115	M	33	24.6	32.6
116	M	31	22.9	31.3
117	M	38	21.3	30.1
118	M	36	22.5	29
119	M	33	23	34.3
120	M	31	24.4	28.9
121	M	34	23.3	31.7
122	M	40	25.1	32.6
123	M	35	23.7	31.8
124	M	37	24.5	33.1
125	M	34	22.4	29.5
126	M	42	22.1	32.7
127	M	34	26	36.1

128	M	33	24.9	32.6
129	M	33	23.8	31.7
130	M	29	25.1	32.4
131	M	28	26.1	34.2
132	M	40	29.1	33.1
133	M	34	27.6	32.3
134	M	40	29.8	31.5
135	M	32	22.4	31.8
136	M	29	28.9	34.8
137	M	41	24.7	33.7
138	M	51	22.4	32.3
139	M	37	22.6	31.4
140	M	22	25.2	31.5
141	M	24	27.9	32.1
142	M	19	29.9	31.7
143	M	36	21.9	33.1
144	M	41	26.9	32.8
145	M	34	27.1	29.5
146	M	36	30.2	33.2
147	M	34	29	31.7
148	M	39	29.1	32.6
149	M	33	28.4	31.7
150	M	30	27.1	28.9
151	M	32	30.2	34.2
152	M	35	27.1	29
153	M	39	29.1	30.1
154	M	32	28	31.3
155	M	34	29	32.6
156	M	36	28.5	31.3
157	M	29	26.9	31.5
158	M	39	27.9	32.7
159	M	33	27.9	29.1
160	M	33	28.7	30.4
161	M	29	29.9	34.5
162	M	30	30.1	35.1
163	M	40	27.4	33.9
164	M	33	36.9	37.1
165	M	27	37	37.9
166	M	40	29	30.9
167	M	44	30.9	33.5
168	M	25	36.4	37.1
169	M	21	30.3	38
170	M	30	30.2	30.9
171	M	40	29.2	33.5

172	M	33	31.9	37.1
173	M	27	28.5	32.9
174	M	20	36.9	37.8
175	M	20	28.9	29.9
176	M	20	35.9	37.7
177	M	41	37.8	39.1
178	M	30	36.2	37.1
179	M	42	32.2	33.3
180	M	48	30.8	32.7
181	M	39	32.8	33.5
182	M	29	33.9	34.4
183	M	22	35.6	35.9
184	M	44	34.5	35.6
185	M	32	34.9	36.6
186	M	29	32.4	33.3
187	M	19	29	30
188	M	32	31.9	33
189	M	40	28.9	29.9
190	M	34	35.9	36.1
191	M	35	30.9	30.9
192	M	20	32.6	33.2
193	M	25	36.1	38.4
194	M	27	30.9	32.5
195	M	40	34.5	36.1
196	M	45	30.4	30.9
197	M	44	29.9	33.2
198	M	49	31.3	32.4
199	M	35	29.8	30.8
200	M	29	28.9	29.9

APPENDIX 9

Table showing the averages of the raw data obtained by Examiner 1 and Examiner 2

No.	Gender	Age	Mandibular inter-canine distance (mm)	Maxillary inter-canine distance (mm)
1	F	22	28	33.2
2	F	22	27	33
3	F	32	32	35
4	F	26	26.4	33.1
5	F	29	21.7	30
6	F	26	22	29.3
7	F	36	23.6	29.2
8	F	27	27.3	32.4
9	F	30	22.9	28
10	F	22	21.8	27.3
11	F	26	30.2	35.4
12	F	21	29.1	35.9
13	F	38	23.9	29.8
14	F	28	24.8	29
15	F	31	29.6	34.7
16	F	37	23.4	29.1
17	F	35	21.6	26.4
18	F	28	29	34.3
19	F	23	23.1	29.2
20	F	27	27.3	33.1
21	F	38	23.7	29.7
22	F	31	28.1	33.3
23	F	26	21.7	27
24	F	21	23.4	28.8
25	F	36	27.7	32.3
26	F	28	29.6	34.9
27	F	34	31.1	36.8
28	F	27	26.2	32.6
29	F	22	23.2	28
30	F	20	21	26.3
31	F	31	24.6	29.2
32	F	34	23.2	28.4
33	F	22	21.9	25.9
34	F	24	30.7	35.3
35	F	32	23	28.4
36	F	20	21.7	27.1
37	F	21	21.3	28.7
38	F	32	23.6	29.1
39	F	26	21.7	28.2

40	F	24	26.1	33.1
41	F	21	23.3	29.7
42	F	37	21.8	26.2
43	F	30	23.2	29.8
44	F	27	29.3	33.2
45	F	24	27.7	30.7
46	F	30	30.9	32.9
47	F	28	27.1	29.7
48	F	19	30.7	35.1
49	F	22	27.1	29.9
50	F	24	29.2	30.7
51	F	38	29.3	30.4
52	F	40	28.4	30.9
53	F	44	29.5	33.2
54	F	30	30	33.8
55	F	32	28.7	32.1
56	F	27	27.1	29.1
57	F	24	26.9	28.7
58	F	28	27.4	30.7
59	F	30	28.7	31.8
60	F	22	30.8	32.2
61	F	34	27.7	28.9
62	F	24	27.2	30.2
63	F	27	30.3	32.2
64	F	40	29.4	34.1
65	F	44	28.6	30.7
66	F	45	27.7	29.9
67	F	32	27.6	33.3
68	F	20	29.3	32.9
69	F	25	29.4	32.9
70	F	25	28.9	31.1
71	F	27	28.7	30.1
72	F	30	27.2	29.2
73	F	31	29.3	31.9
74	F	38	27.4	28.4
75	F	29	26.7	27.3
76	F	32	27.5	29.9
77	F	31	30.4	32.2
78	F	40	30.2	31.4
79	F	28	29.1	31.7
80	F	27	27.7	29.2
81	F	22	28.2	33.2
82	F	22	29.4	33
83	F	21	29.9	32.9

84	F	27	27.8	30.2
85	F	29	27.9	29.7
86	F	40	30.7	34.9
87	F	33	31.8	31.7
88	F	22	29.9	35.1
89	F	39	28.7	33
90	F	43	29.9	32.2
91	F	19	29.2	30.9
92	F	30	29.3	33
93	F	35	28.4	33.2
94	F	39	27.5	30.9
95	F	42	30.9	33.8
96	F	21	30.7	34.7
97	F	23	30.1	34.2
98	F	45	29.9	32.9
99	F	23	30.3	33.8
100	F	22	27.7	29.9
101	M	31	27	37
102	M	36	24.8	32.6
103	M	20	24.9	32.2
104	M	19	26.1	27.4
105	M	27	27.1	32.2
106	M	29	28.2	37.2
107	M	30	27.5	34.9
108	M	32	28.7	33.7
109	M	19	24.2	31.9
110	M	29	28.4	30.3
111	M	32	21.8	29.1
112	M	38	23.4	32.7
113	M	31	25.1	31.5
114	M	35	21.8	32.1
115	M	33	24.6	32.6
116	M	31	22.9	31.3
117	M	38	21.3	30.1
118	M	36	22.5	29
119	M	33	23	=34.2
120	M	31	24.4	28.9
121	M	34	23.3	31.7
122	M	40	25.1	32.6
123	M	35	23.7	31.8
124	M	37	24.5	33.2
125	M	34	22.4	29.5
126	M	42	22.1	32.7
127	M	34	26	36.1

128	M	33	24.9	32.7
129	M	33	23.8	31.6
130	M	29	25.1	32.4
131	M	28	26.1	34.2
132	M	40	29.1	33.1
133	M	34	27.6	32.3
134	M	40	29.7	31.5
135	M	32	22.4	31.8
136	M	29	28.9	34.8
137	M	41	24.7	33.7
138	M	51	22.4	32.3
139	M	37	22.5	31.4
140	M	22	25.2	31.5
141	M	24	27.9	32.1
142	M	19	29.9	31.7
143	M	36	21.9	33.1
144	M	41	26.9	32.7
145	M	34	27.1	29.5
146	M	36	30.2	33.2
147	M	34	29	31.8
148	M	39	29.1	32.6
149	M	33	28.4	31.7
150	M	30	27.1	28.9
151	M	32	30.2	34.2
152	M	35	27	29
153	M	39	29.1	30.1
154	M	32	28	31.3
155	M	34	29	32.6
156	M	36	28.6	31.3
157	M	29	26.9	31.5
158	M	39	27.9	32.7
159	M	33	27.9	29.1
160	M	33	28.6	30.3
161	M	29	29.9	34.5
162	M	30	30.1	35.1
163	M	40	27.4	33.9
164	M	33	36.9	37.1
165	M	27	37.1	38
166	M	40	29	30.9
167	M	44	30.9	33.5
168	M	25	36.4	37.1
169	M	21	30.3	38
170	M	30	30.1	30.9
171	M	40	29.2	33.5

172	M	33	31.9	37.1
173	M	27	28.6	32.9
174	M	20	36.9	37.8
175	M	20	28.9	29.9
176	M	20	35.9	37.7
177	M	41	37.9	39.1
178	M	30	36.2	37.1
179	M	42	32.2	33.3
180	M	48	30.8	32.7
181	M	39	32.7	33.5
182	M	29	33.9	34.4
183	M	22	35.6	35.9
184	M	44	34.5	35.7
185	M	32	34.9	36.6
186	M	29	32.4	33.2
187	M	19	29	30
188	M	32	31.9	33
189	M	40	28.9	29.9
190	M	34	35.9	36.1
191	M	35	30.9	30.9
192	M	20	32.6	33.2
193	M	25	36.1	38.4
194	M	27	30.9	32.5
195	M	40	34.5	36.1
196	M	45	30.4	30.9
197	M	44	29.9	33.2
198	M	49	31.2	32.3
199	M	35	29.9	30.9
200	M	29	28.9	29.9