Anthropometric Analysis of Maxillofacial Foramina in Skulls of Four Human Populations Using Electronic Calliper and 3D Laser Scanning Methods

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بسم الله الرحمن الرحيم

In the name of Allah the most Gracious the most Merciful

Declaration of Authorship

I hereby declare that this thesis is of my own composition, and that it contains no material previously submitted for the award of any other degree. The work reported in this thesis has been executed by myself, except where due acknowledgement is made in the text.

Ibrahim Abead Alayan

Abstract

This study was undertaken to identify the landmarks that would provide the most reliable and predictable indicators of the position of the supraorbital, infraorbital, mental and mandibular foramina in human skulls of Hokien, Hylam, Indian and British populations of ranging ages, which would provide clinicians with suitable modifications in technique to accommodate these variations. Measurements were taken using both electronic digital callipers and 3D laser scanning. Electronic digital calliper measurements were made to estimate how far each foramen was from specific anatomical landmarks on the skulls. An apparatus was developed to position the skulls securely so that the measurement points could be accurately identified, then an electronic digital calliper was used to measure the distance between the defined points. In addition, the same skulls were also scanned using a FastSCAN™ Polhemus Scorpion™ handheld laser scanner, and imported into 3D modelling software (FreeForm Modelling Plus™). This 3D software integrates a PHANYOM™ desktop arm and a haptic force feedback device that provides the user with a sense of touch. Accordingly, with the "Ruler" tool, the measurements between various foramina and defined anatomical landmarks were measured. Measurements made by electronic digital calliper were compared statistically with those made using the 3D scanning method, and overall there was good correlation between the two, indicating that 3D scanning could be used as an alternative method.

With regard to age changes in the skulls, the ages of the Hokien and Hylam groups were known, having been recorded from death records, but the Indian and British skulls were not of known age. In a preliminary study the known age skulls were used to validate the methods of Miles (1962) and Brothwell (1981) who aged skulls using tooth wear patterns. The decision was taken to use the Brothwell chart for the assessment of age in the Indian and British skulls in the main study.

For each of the four population groups, intra-population comparisons of the measurements were made between right and left sides, and between skulls of young and old individuals, also inter-population comparisons between ipsilateral measurements were made. The correlation between the obtuseness of the mandibular

angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible were made on both sides of the skulls of each population group.

Non-significant differences were found between the measurements on right and left sides for the skulls of all populations. There were significant differences between some ipsilateral measurements but although there were statistically significant, they were not considered to be clinically significant. There were no significant differences between ipsilateral measurements with increasing age of the skulls. Also there were weak correlations between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible on both sides of the skulls of each population group. There were good statistically agreements between the electronic digital calliper and 3D laser scanning measurements in all groups and the two methods may be used interchangeably. However 3D scanning is a digital process and therefore the scans could be accessed remotely, either across the internet or by CD.

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Abbreviations

CNCC	Cranial neural crest cells.
DNA	Deoxyribonucleic acid.
c-cad	Cadherin-catenin complexes.
ECM	Extracellular matrix.
Prx	Paired related homeobox genes.
Shh	Sonic hedgehog.
Runx2	Runt-related gene 2.
SHSF	Split hand/split foot disease.
BMPs	Bone morphogenetic proteins.
TGFβ	Transforming growth factor β.
Dlx	Distal-less homeobox.
Msx	Msh homeobox.
M1	First molar.
M2	Second molar.
M3	Third molar.
SD	Standard deviation.
CT	Computerised tomography.
.stl	Stereolithography files.

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Chapter 1
Introduction

The supraorbital, infraorbital, mental and mandibular foramina are important anatomical structures representing the origins / terminations of the nerve plexus canals.(see Fig 17, page110) Accurate knowledge of their positions is strategically important for diagnostic and clinical procedures such as the administration of regional anaesthesia, performance of periapical surgery, surgical extractions, endodontics, implant placement and osteotomy. Reported anatomical positions have been inconsistent with standard anatomy and radiology textbooks which often contain conflicting statements regarding their positions.

The supraorbital, infraorbital, mental and inferior alveolar nerves emerge through the supraorbital, infraorbital, mental and mandibular foramina respectively and supply the cutaneous area of the maxillofacial region. The most common anaesthetic methods used in this area, for procedures such as closure of facial wounds, biopsies, scar revisions, and cosmetic cutaneous surgeries, are nerve blocks. Effective and accurate anaesthesia will be achieved only when the operator has a good and accurate knowledge of the positions of exits of the nerves supplying these areas (Gupta, 2008).

1.1 Supraorbital Foramen

The supraorbital exit sometimes appears either as a foramen or notch, but in this thesis the term supraorbital “foramen” is used for both types.

Webster *et al*.(1986) pointed out that the neurovascular bundles which supply the soft tissues of the forehead pass not only through the supraorbital and supratrochlear notches but also via the supraorbital and supratrochlear foramina which lie superior to the supraorbital rim.

The foramina and notches which lie at or close to the junction of the medial one third and lateral two thirds of the superior orbital rim are known as supraorbital notches or foramina, and the neural and vascular structures which pass through these are known as supraorbital vessels or nerves.

In maxillofacial surgery, knowledge of variations in location of the supraorbital foramina allows an accurate approach, lowers morbidity, facilitates the surgeon's intervention, and increases successful results (Nurten *et al.*, 2008; Turhan-Haktanır *et al.*, 2008). Several authors have stated that a detailed anatomical knowledge is required for planning surgical intervention of the forehead region, open and endoscopic forehead lifting surgery, for achieving effective nerve block and avoiding neurovascular trauma when administering local anaesthesia (Saylam *et al.*, 2003; Nurten *et al.*, 2008; Turhan-Haktanır *et al.*, 2008).

1.2 Infraorbital Foramen

The infraorbital nerve emerges onto the face through the infraorbital foramen. It is responsible for the sensory innervation of the area of the face from the lower eyelid to the upper lip and vestibular gum of the anterior and premolar teeth (Macedo *et al.*, 2009). Knowledge of the landmarks of the infraorbital foramen, groove and canal is very important in the following clinical situations: successful block anaesthesia and surgical process, in the evaluation of medico-legal questions (Mustafa *et al.*, 2001; Apinhasmit *et al.*, 2006), the performance of the surgical treatments such as rhinoplasty, Caldwell-Luc operations, tumour surgery, reduction of the orbital floor, malar fractures, the Le Fort I type osteotomies and surgery of the anterior and superior wall of the maxilla. Second division trigeminal neuralgia is often treated by injecting the infraorbital nerve with neurolytic solutions (Kazkayasi *et al.*, 2003). Also it is essential for endoscopic procedures (Cutright *et al.*, 2003), modern surgical procedures to the orbit (Karakas *et al.*, 2003), the performance of the infraorbital block more easily, viewer time consuming and more satisfactory (Lee *et al.*, 2006), and in surgical and anaesthetic procedures in which the infraorbital foramen is used as a reference point (Macedo *et al.*, 2009). On the other hand it is necessary to avoid administration of anaesthetic agents in the incorrect position which may result in a number of complications such as bleeding, neuropathies, or ineffective anaesthesia (Canan *et al.*, 1999).

1.3 Mental Foramen

Identification of anatomical anomalies in the mandible is of utmost importance in the following clinical situations: the differentiation of the true anatomical structures from non-existing pathology in the mandible, (Azaz & Lustmann, 1973), diagnostic and clinical procedures, the achievement of effective mental nerve block, the avoidance of neurovascular bundle injuries which pass through the mental foramen (Santini & Land, 1990; Moiseiwitsch, 1998; Cutright *et al.*, 2003; Apinhasmit *et al.*, 2006; Apinhasmit *et al.*, 2006; Tulika, 2008), the development of a new minimal invasive surgical technique (Oliveira *et al.*, 2009), the placement of dental implants in this area (Sawyer *et al.*, 1998; Greenstein & Tarnow, 2006; AL-Khateeb *et al.*, 2007; Greenstein *et al.*, 2008), the placement of implants in the edentulous mandible (Captier *et al.*, 2006; Amorim *et al.*, 2008), the performance of endoscopic surgery (Cutright *et al.*, 2003), the localisation of the important maxillofacial neurovascular bundle passing through it (Prabodha & Nanayakkara, 2006), the administration of local anaesthesia for dental procedures and in teaching and interpreting anatomical landmarks in oral pathology and forensic medicine (Neo, 1989). Moreover, knowledge of the position of the mental foramen and the frequency of accessory mental foramina is necessary for dental implant surgery and any surgical procedure in the mandibular posterior teeth area (Balcioglu & Kocaelli, 2009).

Moreover, radiographically, failure to know variations in position of the mental foramen may cause a misdiagnosis of a radiolucent lesion in the apical area of the mandibular premolar teeth. Clinically, the mental bundle could be injured during surgical procedures and local anaesthesia may fail if the mental foramen is not located precisely (Green, 1987; Neo, 1989; Phillips *et al.*, 1990; Ngeow & Yuzawati, 2003; Yesilyurt *et al.*, 2008).

1.4 Mandibular Foramen

One of the most commonly used local anaesthetic injections in dental clinics today is the local anaesthetic block of the inferior alveolar nerve which has been available to the dentist for more than a hundred years. However, it is often cited as the dental procedure with the highest failure rate. To lower the rate of failure, the operator must have a good knowledge of the exact location of the mandibular foramen, as the success of this technique is dependent on administration of anaesthetic agents close to the mandibular foramen (Galbreat.Jc & Eklund, 1970; Blanton & Jeske, 2003; Tsai, 2004).

The knowledge of the location of the mandibular foramen is necessary in the following clinical situations: the performance of a local anaesthetic block of the inferior alveolar nerve (Nicholson, 1985), the practice of dentistry and medicine (Hayward *et al.*, 1977), and may be of great help to successful surgery or to interpret lateral cephalograms, reconstructive surgery and anthropological assessments (Kilarkaje *et al.*, 2005).

It can be concluded from the many recent papers that an accurate knowledge of the variation in location of facial foramina remains an important consideration in alveolar dentistry and maxillofacial surgery.

Chapter 2
Literature Review

2.1 Supraorbital Foramen

2.1.1 Papers Related to Studies Using Dry Skulls

Webster *et al.*(1986) studied one hundred and eight Indian adult skulls to determine the location of the supraorbital foramen using a calliper and a metric ruler. Age at death and sex were not reported. 49.07% of skulls had bilateral supraorbital notches, 25.93% had bilateral foramina, whereas, 25% had unilateral either a notch or a foramen. In the transverse plane, the mean distance between the medial edge of the supraorbital foramen and the midline was 32.02 mm. In the vertical plane, the mean distance from the inferior edge of supraorbital foramen to the inferior edge of supraorbital rim was also 1.56 mm. In addition, the mean diameters of the foramina were 3.78 mm for foramina and 5.70 mm for notches.

Chung *et al.*(1995) studied the morphology and locational relationship of the supraorbital, infraorbital, and mental foramina, using photographs of one hundred and twenty four Korean skulls there being thirty five male, eighteen female and seventy one unknown sex. The age at death of skulls ranged from 18 to 90 years with a mean of 65.4 years. The supraorbital, infraorbital, and mental foramina were on the same sagittal plane in 38.1% of cases. The supraorbital notch 69.9% was found more frequently than the supraorbital foramen 28.9%. The mean distance from the median plane to the centre of the supraorbital foramen was 22.7mm. The mean length of the line from the centre of the supraorbital foramen to the centre of the infraorbital foramen was 45.6 mm.

Beer *et al.*(1998) reported a study of five hundred and seven adult prehistoric to the twentieth century European skulls. Age at death and sex of the samples were not evaluated. The anatomical measurements on the skulls were carried out using callipers. The examinations were concentrated on the configuration (notch/foramen) the number of exit points on the supraorbital rim, and the vertical distance from the supraorbital rim. This study showed that 74% of the skulls exhibited bilateral asymmetry. The mean distances from the supraorbital foramen to the nasion were 31 mm. The largest vertical distance from the supraorbital foramen to the supraorbital rim was 19 mm. The authors concluded that surgical procedures must be done under direct vision with great caution due to many variations that exist.

Hwang and Baik (1999) measured the distance between the supraorbital notch and the supraorbital fissure. The measurements were made on eighty two orbits of forty one adult Koreans skulls of unknown age, using callipers. The sex of the skulls was determined. The distance between the supraorbital notch and the supraorbital fissure was 40.0 (± 2.5) mm. This distance was greater in male skulls than in female skulls. However, there was no significant difference in measurements between contralateral sides in either sex.

Hanihara and Ishida (2001) reviewed a series of descriptive reports on discrete cranial traits in eighty one human populations. Age at death was not reported. Significant intertrait associations were found between the accessory infraorbital and supraorbital foramina in the pan Pacific region and Sub-Saharan African samples. With a few exceptions, the occurrence of a supraorbital foramen was predominant in females.

Gumusburun *et al*.(2002) stated that a total of three hundred and sixty adult Anatolian-Ottoman skulls there being two hundred and twelve males, one hundred and forty eight females of unknown age were examined to characterize the foramina in the supraorbital region. They reported the following supraorbital traits: 93% in medial, 6.7% in both medial and lateral, only 0.3% in lateral position. Of three hundred and sixty skulls, 54.7% had one notch on either side, 8.9% had one foramen on one side and one notch on the other side, 6.7% had one foramen and notch on one side and one notch on the other side, 5.3% had one foramen on either side and 24.4% had other combinations. The distances of the notches from the midline, and between of the foramina from the midline and the supraorbital margin were measured.

Karakas *et al*.(2003) studied sixty two orbits obtained from thirty one skulls of male adult Caucasians, aged between 30-50 years, by dentition, using a millimetric compass. The supraorbital foramen was considered as the main reference point on the superior orbital wall. The distances from the supraorbital foramen to the midpoint of the superior orbital fissure, the fossa for the lacrimal gland and the superior aspect of the optic canal were 46 mm, 26 mm and 45 mm respectively. Accordingly, they concluded that there were no significant differences in the measurements between this study and the study of Rontal *et al.* (1979) using Indian skulls.

Saylam *et al*.(2003) studied two hundred crania. The age, sex, and the ethnic group of the samples were not reported. There was a supraorbital notch in 77% of the subjects and a foramen in 23% of the subjects. The mean distance from the supraorbital foramen to the midline was 25.23 mm. The mean distance between the frontal and supraorbital foramina was 4.99 mm.

Agthong *et al.*(2005) determined the different anatomical variations of the supraorbital foramina with respect to sex and side. One hundred and ten adult skulls of unknown ethnic group or age at death were used. Sex was determined for each skull by standard forensic medical criteria resulting in seventy skulls being classified as male and forty as females. The distance from the centre of the supraorbital to midline was measured bilaterally. The results revealed that the mean distance from the left supraorbital foramen to midline in females 24.2(± 0.4) mm were significantly lower than that in males 25.6(± 0.5) mm.

Cheng *et al*.(2006) studied ninety seven adult Chinese skulls to determine the location of the supraorbital nerve exit, contralateral and sex comparison were made, though the age of the skull at death was not known in this study. Supraorbital exits were found in all skulls of which 45.9% were foramina, the remaining being notches. The median distance between the supraorbital exit and the facial midline was 24.56 mm. The study concluded that the position of the supraorbital exit occurred toward the medial aspect of the superior orbital rim.

Apinhasmit *et al.*(2006) determined the location of the supraorbital notch/foramen in one hundred and six Thai adult skulls of known age and sex of six seventy males and thirty nine females. The age of the skulls ranged between 18 and 83 years. The mean distance of the supraorbital foramen from midline was 25.14 (± 4.29) mm, temporal crest of the frontal bone was 26.57 (± 3.92) mm and the supraorbital rim was 3.15 (± 1.29) mm. the mean vertical distances from the infraorbital to the supraorbital foramina and to the occlusal plane of the upper teeth were 44.95 (± 2.96) mm and 42.52 (± 3.89) mm respectively.

Huanmanop *et al.*(2007) studied fifty adult Thai skulls of twenty five males and twenty five females. Sex of each skull was determined using standard forensic medicine criteria. The age at death of the subjects was unknown. The distances from the anatomical landmarks to the supraorbital foramen in the medial, superior; inferior and lateral walls were measured. The mean distances from the supraorbital foramen in the roof to the superior orbital fissure, the optic canal and lacrimal foramen were 44.7mm, 40.0 mm, and 33.6 mm, respectively. The study observed that there were significant differences in several measurements between sides and sexes.

Shimizu *et al*.(2008) reported that the distance between the supraorbital rim and the inferior margin of the supraorbital foramen was measured on ninety specimens. The mean distances from the inferior margin of the foramen to the supraorbital rim in low position was 1.16 mm, whereas in high position was 4.0 mm.

Gupta (2008) took measurements from adult dried human skulls to determine the position of the supraorbital foramina. Seventy nine adult skulls from a North-West Indian subcontinent, of unknown sex and age at death were used in this study. The supraorbital exit was a foramen in 35.4% and a notch in 64.6% on the right side, while, it was a foramen in 55.7% and a notch in 44.3% of skulls on the left side. The mean distances of the supraorbital foramen to the midline was approximately 24 mm, to the temporal crest of the frontal bone was 30 mm and to the supraorbital rim, when a foramen, it was 2.5 mm and it was ranged from 1.6 mm to 10.4 mm, when a notch. Additional exits for branches of the supraorbital nerve were present in 14% of skulls. In about 80% of skulls, the supraorbital, infraorbital, and mental foramina were along the same vertical line.

Trivedi *et al.* (2010) studied two hundred and thirty three human skulls of unknown age and sex to evaluate the anatomy of the supraorbital foramen. The supraorbital exit had bilateral supraorbital notches in 35.62%, bilateral supraorbital foramina in 21.45% and a notch on one side and a foramen on other side in 16.73% of cases. The mean distances from the supraorbital foramen to the midline were 24.30 mm and 23.73 mm on the right and left sides respectively.

Ashwini *et al*. (2012) studied eighty three adult human skulls using a "travelling vernier's microscope". The sex of the specimens was unknown. The skulls were obtained from the cadavers of South Indian population. The mean distances from the supraorbital foramen to the midline was 22.24 mm on the right side and 22.2 mm on the left side, to the fronto-zygomatico suture was 29.34 mm on the right side and 28.7 mm on the left side. Furthermore, the mean distance from the lowest point of the supraorbital foramen to the supraorbital rim was 3.5 mm on the right side and on the left side was 3.04 mm. It was concluded that there was a differences with regard to the position and dimensions of supraorbital foramen between populations of the different regions.

2.1.2 Papers Related to Studies Using Radiography

Kazkayasi *et al*.(2008) reported that a topographical anatomic examination of 30 adult skulls was done to study the location and dimensions of the supraorbital foramina. The sex, the age at death and the ethnic group of the skulls were not reported. This study showed that the supraorbital exit was a foramen in 41%, a notch in 49%, and a groove in 10% of cases. A total of 33% supraorbital foramina were inside the frontal sinus and the mean distance was 6.3 (± 1.34) mm from the lateral border of the sinus; 45% of supraorbital foramina were outside of the frontal sinus and the mean distance was 8.8 (± 2.01) mm; 22% of supraorbital foramina were at the border of the frontal sinus.

Tsui (2009) illustrated that ultrasound imaging is a safe simple non-invasive modality to locate foramina through which nerve structures emerge. Sonographically, bone appears as a white line with an underlying dark shadow. Any discontinuity within the white line may indicate either an anatomical defect or a foramen in the bone. Typically, all foramina lie in the line parallel to the sagittal plane on each side of the face. Approximately, the mean distances from supraorbital, the infraorbital and the mental foramina in adults to the midline were 25 mm.

2.1.3 Papers Related to Studies Using Cadavers

Aziz *et al.*(2000) reported that forty seven cadavers of unknown age and ethnic group were dissected to expose the supraorbital foramen. The distances between the supraorbital foramen to the infraorbital foramen and the facial midline were measured. The study revealed that the mean distances between the supraorbital and infraorbital foramina in males were 43.3 (± 3.1) mm and in females were 42.2 (± 2.4) mm, whereas, between the supraorbital notch and the midline was 26.5 (± 3.5) mm and 26.3 (± 3.3) mm respectively. It was concluded that there were no statistically significant differences between the left and right sides or between sexes.

Mowlavi *et al.*(2002) described bony anatomical landmarks from seven fresh cadavers of unknown sex, ethnic group, and age at death. The supraorbital notch was chosen as the guideline landmark. The inferior oblique muscle originates from the orbital floor, 5.14 (± 1.21) mm posterior to the inferior orbital rim, on a line extending from the infraorbital foramen to 10 (± 0.9) mm to the supraorbital foramen. Identification of the orbital rim, infraorbital foramen, and supraorbital notch allowed accurate identification of the ethnic group and course of the inferior oblique muscle.

Cutright *et al.*(2003) studied eighty cadaveric heads of twenty white males, twenty black males, twenty white females, and twenty black females of known race, and the position of the supraorbital foramina was evaluated. The age at death of cadavers was not reported. The data showed that the mean distances from the supraorbital foramen to midline was 25 mm and to the temporal crest was 26 mm. It was concluded that there were significant differences in foraminal position between both races and between sexes.

Saylam *et al.*(2003) studied fifty cadavers of unknown sex, age, and ethnic group. The supraorbital exit presented as a notch in most subjects. The mean distance from the supraorbital foramen to medial canthus was 9.87 mm, and to the frontal foramen was 5.37 mm.

Erdogmus and Govsa (2007) reported that the location of the supraorbital foramen was investigated by injection of the arterial bed with red-dyed latex in thirty eight cadavers of unknown sex, ethnic group, and age at death. The distance from the supraorbital foramen to the midline at the level of the supraorbital rim ranged from 20 to 32 mm.

Smith *et al*.(2010) stated that the position of the supraorbital foramen in relation to palpable anatomical landmarks was evaluated using a digital calliper. In this study, fourteen Caucasian cadavers of six males and eight females with an age ranged from 46 to 88 years were investigated. The distances from the supraorbital to the zygomaticofrontal suture and the inferior orbital rim at the zygomaticomaxillary suture were taken. The study showed that the supraorbital foramen was located 26.2 (± 2.8) mm medial and 13.5 (± 3.7) mm superior to the zygomaticofrontal suture. Vertical measurements made from the zygomaticomaxillary suture to the supraorbital foramen was 34.4 (± 3.6) mm. It was concluded that this may facilitate correct localising of the supraorbital foramen in patients with missing teeth or fractures of the maxillary bone, during surgery.

2.1.4 Papers Related to Studies Using Scanning Methods

Nurten *et al*.(2008) reported that the anatomic variations of the supraorbital foramina in living crania was determined by multi-detector CT scan on 3 D volume-rendered images in three hundred and ninety nine white patients, two hundred and seven males and one hundred and ninety two females. Age, sex, and side were taken into consideration. The mean distances from the supraorbital foramen to midline was 23.6 (± 3.9) mm. In this study, there were positive correlations between both sides for the distances to the midline.

2.2 Infraorbital Foramen:

2.2.1 Papers Related to Studies Using Dry Skulls

Matsuda (1927) reported on the location of the infraorbital foramen in three hundred and eighty maxillary bones. The age at death, sex, and ethnic group of samples were unknown. Vertically, the distance between the upper border of the infraorbital foramen and the lower margin of the infraorbital rim was 4.5 to 10.0 mm and the distance from the lower border of the alveolar process to the lower border of the infraorbital was 34.5 to 36.0 mm with approximately the same distances on both sides. The infraorbital foramen was also located in relation to the upper teeth on both sides; it was found usually opposite the upper second premolar and the next most common position was opposite the space between the upper first molar and upper second premolar.

An evaluation the location of the infraorbital foramen in a transverse plane of six skulls was undertaken by direct skull and radiographic measurements in unrepaired cleft palate and non-cleft individuals (McKinstry, 1987). The age, sex and ethnic group of the skulls were known. In the transverse plane, the left infraorbital foramen was significantly superior to the right infraorbital foramen in the cleft palate skulls, which was suggestive of a vertical deficiency of the maxilla on the cleft side. Whereas, there were no significant differences with regard to transverse location of the infraorbital foramina between the cleft skull groups with regard to sex or age.

Triandafilidi *et al.*(1990) described the position of the infraorbital foramen in 55 male crania. The age and ethnic group of the skulls were not determined. The inferior orbital rim, the zygomatico-alveolar crest and the anterior nasal spine were used as landmarks. This study showed that the distances from the infraorbital foramen to the anterior nasal spine and to the zygomatico-alveolar crest were equal and forms the vertex of an isosceles triangle. The mean distance between the infraorbital foramen and the infraorbital rim was 7.19 mm.

Hindy and Abdel-Raouf (1993) reported on the position of the infraorbital foramen in thirty Egyptian adult skulls of unknown sex and age. The mean distances from the centre of the foramen to the infraorbital rim and to the lateral nasal border were 6.1 (± 2.4) mm and 14.7 (± 2.7) mm. In relation to the maxillary teeth, the infraorbital foramen was above the second maxillary premolar in 50% of skulls, above the first premolar in 15% and above the space between the first and second premolar teeth in 15% of skulls.

Chung *et al.*(1995) studied the morphology and locational relationship of the supraorbital, infraorbital and mental foramina from photographs of one hundred and twenty four Korean skulls there being thirty five males, eighteen females and seventy one of unknown sexes. The age at death of skulls ranged from 18 to 90 years with a mean of 65.4 years. The infraorbital foramen was on the sagittal plane passing through the supraorbital foramen in 36.4%, or lateral to the plane in 63.6% of cases. The mean distances from the centre of the infraorbital foramen to the median plane and to the infraorbital margin were 27.2 mm and 8.6 mm respectively.

Hwang and Baik (1999) studied eighty two orbits obtained from forty one adult Korean skulls of known sex. Measurements were made using callipers. The age of the skulls at death was not determined. The mean distances from infraorbital foramen to the infraorbital fissure, where the infraorbital groove started, was 26.4 (± 2.6) mm. The study showed that this distance was significantly greater in the male skulls compared to female skulls.

Karakas *et al.*(2003) studied the location of the infraorbital foramen in sixty two orbits obtained from thirty one skulls of adult male Caucasians; direct measurements were undertaken using a millimetric compass. These skulls were aged between 30-50 years by dentition. The distances from the infraorbital foramen to the midpoints of the lateral margin of the fossa for the lacrimal gland was 23.8 (± 7.2) mm, inferior orbital fissure was 31.9 (± 3.9) mm, inferior orbital rim was 6.7 (± 1.9) mm and the inferior aspect of the optic canal was 50.3 (± 3.2) mm. The results concluded that there were some differences in the measurements between this study and both the study of Ronta *et al.* (1979) using Indian skulls and the study of Hwang and Baik (1999) using Korean skulls.

Elias *et al*.(2004) using two hundred and ten adult Caucasian skulls reported on the location of the infraorbital foramen in both the sagittal and transversal planes. The direct measurements were undertaken with a digital calliper. Variations in form and symmetry with the contralateral foramen were also reported. The age at death and sex were not determined. In the sagittal plane, the distance of the superior margin of the infraorbital foramen to the infraorbital rim was 6.71 mm and 6.83 mm on the right and left sides respectively. In the transversal plane, the distance of the medial margin of the infraorbital foramen to the lateral margins of the piriformis opening was 13.28 mm on the right side and 13.31 mm on the left side. In this study, 24% of cases showed accessory foramina. Absolute symmetry was not observed, and in some cases, the foramina presented as occurring bilaterally or unilaterally.

Agthong *et al.*(2005) used one hundred and ten adult Asian skulls, seventy males and forty females without mandibles and isolated mandibles. The position of the infraorbital foramen related to sex and side was evaluated. The age at death and ethnic group of the skulls were not reported. The distances from the centre of the infraorbital foramen to the anterior nasal spine and to the inferior orbital rim were measured bilaterally. No absence of the infraorbital foramen was observed. The mean distances from the centre of the infraorbital foramina to anterior nasal spine in females were 32.8 (± 0.3) mm on the right and 33.1 (± 0.3) mm on left side, which were significantly lower than that in males 34.8 (± 0.3) mm on the right and 35.0 (± 0.3) mm on left side. The mean distances from the infraorbital foramen to the infraorbital rim in both sexes were 7.8 (± 0.2) mm and 8.0 (± 0.3) mm on the right and left sides respectively.

Apinhasmit *et al*.(2006) studied the location of the infraorbital foramen in one hundred and six Thai adult skulls. The age and sex were given on grave records. The age ranged from 18 to 83 years; there were sixty seven males and thirty seven females. The infraorbital foramen was usually found above the second upper premolar. The mean distances from the infraorbital foramen to the maxillary midline was 28.43 (± 2.29) mm, to the infraorbital rim was 9.23 (± 2.03) mm and to the zygomatico-maxillary suture was 2.15 (± 1.67) mm. The mean vertical distances from the infraorbital foramen to the supraorbital foramen was 44.95 (± 2.96) mm and to occlusal plane of the upper teeth was 42.52 (± 3.89) mm. The study showed significant sex differences in the distances of the infraorbital foramen from different anatomical landmarks, therefore, these measurements were longer in males than in females.

Lee *et al*.(2006) described the position of the infraorbital foramen, and structures around the foramen on forty two Korean skulls of twenty seven males and fifteen females of unknown ages. Structures around the infraorbital foramen were evaluated. These were classified into four types according to the existence of a distinct tuberosity above the infraorbital foramen, and the degree of prominence of the canine fossa. No distinct tuberosity was noted in 38% of cases.

Gupta (2008) reported that measurements were taken on seventy nine adult human skulls of unknown sex and age from a North-West Indian sub-continental population, to determine the position of the infraorbital foramina. The mean distance from the centre of the infraorbital foramen to the inferior orbital rim was 7 mm, the midline was 28.5 mm, zygomatico maxillary suture was 10.8 mm and the supraorbital foramen was 41.8 (± 3.7) mm. The mean distance between the infraorbital foramina of both sides was 53.2 mm, whereas, the result showed that the infraorbital and mental foramina were most often on a vertical line with the second premolar. The distances of the infraorbital foramen from the midline on both sides were similar, proving facial symmetry.

Macedo *et al*.(2009) determined the mean distances between the infraorbital foramen and the infraorbital margin and the piriform aperture on both sides of two hundred and ninety five human skulls. The age, sex, and ethnic group of the sample were not reported. The measurements were obtained with a compass and a calliper in a manner perpendicular to the Frankfurt plane. The mean distance between the infraorbital foramen and the infraorbital margin was 6.28 mm on the right and 6.45 mm on left side. The mean distance between the infraorbital foramen and the piriform aperture was 17.75 mm and 17.60 mm on the right and the left side respectively. This study concluded that there were statistically significant differences between the right and left sides with regards to the distance of the infraorbital foramen and the infraorbital margin.

Boopathi *et al*.(2010) evaluated eighty South Indian adult human skulls. The age and sex were not considered. The infraorbital foramen on both sides in relation to the infraorbital rim was measured using a metal digital vernier calliper. The mean distance of the infraorbital foramen from infraorbital rim was 6.57 (± 1.28) mm, whereas, the mean of the vertical and transverse diameters of the foramen were 2.82 (± 0.79) mm and 2.87 (± 0.78) mm respectively. Accessory foramina of infraorbital foramen were found in 16.25 % skulls. It was concluded that the information of morphological and topographical anatomy of the infraorbital foramen may have an important role and guidance in infraorbital nerve blocks.

2.2.2 Papers Related to Studies Using Radiography

McKinstry (1987) described the location of the infraorbital foramen using cephalographs obtained from files of fifteen complete unilateral left cleft palate patients. The age of individuals ranged from 7-26 years, there being 10 males and 5 females. The same cephalographic technique was used for non-cleft palate patients. In the transverse plane, the left infraorbital foramen was found significantly superior to the right infraorbital foramen in the cleft palate individuals. It was suggested that there was a vertical deficiency of the maxilla on the cleft side.

Kazkayasi *et al.* (2001) studied the location of the infraorbital foramen in thirty five adult skulls, as well as their relationships with different anatomical landmarks using cephalometric analysis. The age and sex of the skulls were not determined. The mean distance from the infraorbital foramen to the infraorbital rim was 7.19 (± 1.39) mm, to the lateral process of the canine tooth in the vertical plane was 33.94 (± 3.15) mm and to the lateral nasal border in the horizontal direction was 17.23 (± 2.64) mm. In this study, there was statistical significant difference between the distances from the centre of the sella turcica to the nasion and the distance from the nasion to the anterior nasal spine.

Suresh *et al*.(2006) reported on a study using computerized tomographic scans of forty eight paediatric patients of unknown sex and ethnic group. The position of the infraorbital foramen was evaluated using an intraoral route or an extraoral route. The result has showed that the distance of the foramen from the midline was

21.3 mm + 0.5 x age (in years). This study found a linear correlation of age to the distance of the infraorbital foramen from the midline.

2.2.3 Papers Related to Studies Using Cadavers

Triandafilidi *et al.*(1990) determined the position of the infraorbital foramen in sixteen cadavers of unknown ethnic group, sex and age at death. The lateral point of the wing of the nose, and the medial canthus were used as landmarks. The results revealed the infraorbital foramen was situated equidistant from the medial canthus and the zygomatico-alveolar crest. The mean distance of the infraorbital foramen from the infraorbital rim was 7.19 mm.

Hindy and Abdel-Raouf (1993) examined the infraorbital foramen in fifteen Egyptian adult human cadavers of unknown sex and age at death. The most common shapes of the infraorbital foramen were single or oval. Usually it was directed downward, forward and medially. The distance from the centre of the foramen to the inferior orbital margin was 6.1 (± 2.4) mm and to the lateral nasal border were 14.7 (± 2.7) mm. The infraorbital foramen was in line with the second maxillary premolar. The anterior superior alveolar nerve arose either from the middle third of the infraorbital nerve in 66.67% or from its anterior third in 33.33% of cases. The middle superior alveolar nerve was not apparent in 53.33% of cases and it arose from the middle third of the infraorbital nerve in 46.67% of cases.

Canan *et al.*(1999) studied forty five cadavers of fourteen females and thirty one males locating the infraorbital foramen by dissection. The age at death and the ethnic group of the cadavers were not known. Two lines perpendicular to each other were drawn; the first line was drawn horizontally between the lateral canthus and medial canthus. This line was divided into three equal parts. The second line was drawn vertically and perpendicular to the point uniting the internal and medial thirds and intersecting the infraorbital margin. The infraorbital foramen was on the line in 75.6% of cases on the right side and in 68.9% on the left side. The distance between the infraorbital foramen and the infraorbital rim was 10.9 mm in males and 8.3 mm in females. In most of cases, the accessary infraorbital foramen was observed, knowledge of which may helpful in decreasing anaesthetic complications.

Aziz *et al.*(2000) studied forty seven cadavers there being twenty four males and twenty three females (33 white, 11 black & 3 Hispanic). The age at death and ethnic group were not reported. The distances between the infraorbital foramen and the inferior orbital rim, the facial midline, and the supraorbital foramen were measured, they being 8.5 (± 2.2) mm, 27.7 (± 4.3) mm and 43.3 (± 3.1) mm in males and 7.8 (± 1.6) mm, 26.2 (± 3.2) mm and 42.2 (± 2.4) mm in females respectively. The most common position of the infraorbital foramen was in line with the first maxillary premolar. The data showed that there were no statistically significant differences between either sides or sexes.

Mowlavi *et al.*(2002) used fresh cadaver heads of unknown sex, ethnic group, and age at death to identify bony anatomical landmarks. The infraorbital foramen was chosen as a baseline landmark. The inferior oblique muscle originates on the orbital floor, 5.14 (± 1.21) mm posterior to the inferior orbital rim, on a line extending from the infraorbital foramen to 10 (± 0.9) mm inferior to the supraorbital notch along the supramedial orbital rim.

Cutright *et al.*(2003) reported on the position of the infraorbital foramina determined from eighty cadaveric heads of twenty white males, twenty black males, twenty white females, and twenty black females. The cadavers were not aged in this study. The mean distance of the infraorbital foramen from the midline was 27 mm and from the inferior orbital rim 6.4 mm. The infraorbital foramen was 0.3 mm medial to the zygomatico-maxillary suture. The study concluded that there was a significant difference in these distances between populations and sexes.

Kazkayasi *et al.*(2003) reported on the morphologic and topographic anatomy and variations of the infraorbital foramen, in ten cadavers. The mean age of cadavers was 40 years; there being three females and seven males. This study reported that the shape of the infraorbital foramen was a round, oval, or semilunar in 40%, 30%, and 30% of cases respectively. The infraorbital foramen was a single in 90% and double or triple in 5% of cases.

Hu *et al.* (2006) described the branching pattern and topography of the infraorbital nerve after dissecting forty three Korean cadavers of unknown sex and age at death.

In most cases, the infraorbital artery was located in the middle (73.8%) and superficial to the infraorbital nerve bundle (73.8%), at its exit from the infraorbital canal.

Song *et al*. (2007) dissected fifty embalmed cadavers of Koreans to expose the infraorbital foramen. The age at death and the sex were not reported in this study. The distance between the bilateral infraorbital foramen was 54.9 (± 3.4) mm and the mean distances of the infraorbital foramen from the ala of the nose were measured directly on the cadavers. The results showed the infraorbital foramen was located 1.6 (± 2.7) mm and 14.1 (± 2.8) mm lateral and superior to the ala of the nose respectively. Whereas, the distance between the ala of the nose and the infraorbital foramen was 15.9 (± 2.8) mm and the horizontal angle was 64.1° (± 9.9) latero-superiorly.

Farah & Faruqi (2008) performed morphometric measurements in sixty maxilla dissected out from thirty human foetuses of intrauterine life between sixteen weeks and thirty four weeks. The subjects were categorised into five age groups. The length of the infraorbital foramen and canal and width of anterior and posterior ends of infraorbital foramen were 4.01mm to 6.00 mm, 0.67 mm to 2.60 mm, 0.64 mm to 1.65 mm and 1.39 mm to 3.01 mm, respectively. The study revealed that the shape of the infraorbital foramen was maintained in most of the age groups. The infraorbital foramen and canal showed variable rates in the growth of lengths with the increase in foetal age. The study showed the infraorbital foramen was approximately 4 mm whereas, the canal was little more than 0.5 mm in group I foetuses. At the end of intrauterine life, there was only one and half times increase in the length of infraorbital foramen, whereas, approximately 4 times increase in the length of canal. This process continues even after birth.

Rahman *et al*.(2009) examined the anatomy of the infraorbital foramen, canal and the angles at which a radiofrequency probe must be directed to enter the infraorbital foramen and canal. Eleven cadaveric skulls were evaluated. The sex, age, and the ethnic group of the cadaveric skulls were not identified. The distance from the foramen to the midline was 26 mm and inferior orbital rim was 8 mm.

Smith *et al*. (2010) studied fourteen Caucasian cadavers, six males and eight females with an age range of 46 to 88 years. The position of infraorbital foramen in relationship to anatomical landmarks was evaluated. A digital calliper was used. The mean distances of the infraorbital foramen from the lateral orbital rim at the zygomaticofrontal suture were 23.8 (± 3.1) mm medially and 30.9 (± 3.8) mm inferiorly and the infraorbital rim at the zygomaticomaxillary suture was 7.6 (± 2.2) mm. It was concluded that the result may be valuable for surgery in patients with missing teeth or fractures of the maxillary bone.

2.2.4 Papers Related to Studies Using Scanning Methods

Lee *et al*.(2006) reported that the position of the infraorbital foramen, and structures around the foramen. Forty two Korean skulls of 27 males and 15 females of unknown ages were studied. The direction of the angle of the infraorbital canal in relation to the median plane and the Frankfurt plane was studied using three-dimensional models. The angle between the infraorbital canal and the median plane was 12° and the Frankfurt plane was 44°. This study revealed that the angle of the infraorbital canal relative to the Frankfurt plane was greater in males than in females by 4°.

Suresh *et al*.(2006) reported on the distance of the infraorbital foramen from the midline, and the relationship between this distance and the age of the patient. Computerized tomographic scans of 46 paediatric patients were used. The age of the patient ranged between 0.8 to 17.75 years. This study implied that the distance of the infraorbital foramen can be predicted by use of the following formula: *Distance of the infraorbital foramen (in mm) from midline = 21.3 + 0.5 x age (in years).* Also there was a linear correlation between the age and the distance of the infraorbital foramen from the midline. These results concluded that anatomical knowledge of the location of the infraorbital foramen may play an important role in accurately positioning a needle during surgical procedures.

Tsui (2009) illustrated that ultrasound imaging was a safe simple non-invasive modality to locate three important facial foramina (supraorbital, infraorbital and mental foramina) through which nerve structures emerge. Sonographically, bone appears as a white line with an underlying dark shadow. Any discontinuity within the white line may indicate either an anatomical defect or a foramen in the bone. All foramina typically lie in a line parallel to the sagittal plane on each side of the face. In adults, the mean distances from the supraorbital, infraorbital and mental foramina to the midline were approximately 25 mm. Generally, the mean distances from the infraorbital foramen to the infraorbital rim were about 10 mm.

Ilayperuma *et al*.(2010) stated that one hundred and eight adult skulls of an adult Sri Lankan population of seventy males and thirty eight females with age ranged between 48-67 years were evaluated. Most infraorbital foramina were positioned in line with the second upper premolar. The most common its position in relation to the supraorbital foramen was laterally to the lateral margin of the supraorbital foramen. In 24.07 % of the skulls, the supraorbital and infraorbital foramina lay in the same sagittal plane. The transverse distance of the infraorbital foramen from the midline was 30.69 (± 3.43) mm in males and 28.40 (± 2.82) mm in females and from the zygomatico-maxillary suture 2.47 (± 1.56) mm in males and 1.76 (± 1.48) mm in females. The vertical distance of the infraorbital foramen from the infraorbital rim was 10.56 (± 1.74) mm in males and 9.02 (± 1.58) mm in females and from the supraorbital foramen were 44.86 (± 3.35) mm in males and 43.26 (± 3.63) mm in females. The results revealed that the mean distances of the infraorbital foramen from anatomical landmarks in males were significantly greater than in females. It was concluded that the results reinforce the variation in the occurrence of the infraorbital foramen among different populations.

2.3 Mental Foramen

2.3.1 Papers Related to Studies Using Dry Skulls

Matsuda (1927) reported on the location of the mental foramen in three hundred and twenty nine mandibles. The age at death, sex, and ethnic group of samples were unknown. The mean distance between the upper borders of the mental foramina to the upper margin of the alveolar process was 10.5 - 18.0 mm and the distance between the lower borders of the mental foramina to the lower border of the mandible was 11.5 - 16.0 mm. The most frequent location of the mental foramen in relation to the lower teeth was below the second premolar.

de Freitas *et al*.(1976) studied the direction of the mental canal in both horizontal and vertical planes on two hundred and seventy five human adult mandibles of one hundred and eighty five men and ninety women from Brazil were used. The age of the samples was not determined. The study showed that the mental canal was oriented postero-latero-superior, antero-latero-superior, and toward both postero-latero-superior and antero-latero-superior in relation to horizontal plane. The postero-latero-superior direction was predominant in both sexes, while an antero-latero-superior direction was more prominent noted in females than in males.

Friedman *et al*.(1985) studied one hundred and twenty four dissected mandibles there being eighty males, and forty four females, of South African Blacks. The age at death was known. A vertical measuring calliper was used. The distances between the inferior borders of the mandible and lower border of the cementoenamel junction of the lower second premolar were measured. The cementoenamel junction was used as a landmark instead of the alveolar crest to overcome the resorption problem as a result of the periodontal disease. The distance between the mental foramen and the inferior border of the mandible was also measured. The proportional ratio between these distances was 2.3:1. The result showed that there were no statistically significant differences between the group as a whole and males or females separately. It was concluded that this ratio can be used to estimate the original height of the body of the mandible in edentulous dissected mandibles of South African Blacks, when the distance between the mental foramen and the inferior border of mandible was known.

Gershenson *et al*.(1986) studied five hundred and twenty five mandibles. The mental foramen was located below the second premolar in 43.66% of cases.

Green (1987) reported on the anteroposterior position of the mental foramen in eighty seven southern Hong Kong, Chinese skulls of known sex. The age ranged from 15 to 81 years. They compared their results with those reported for other population groups. The mean position was below the second premolar tooth, a result similar to that reported for other Mongoloid populations and posterior to the position in Caucasoids and anterior to the position in Black African group.

Green and Darvell (1988) reported that there was a variation in the position of the mental foramen in relation to standing teeth and population groups. The study confirmed that the position of the mental foramen was clearly affected by these factors. The position was investigated in a sample of southern Chinese skulls. The sex of the population was unknown. The age at death was calculated by the degree of tooth wear. There was a highly significant correlation between wear and position; there was no significant contribution between age and tooth size as additional explanatory variables.

Santini and Land (1990) studied sixty eight Chinese and forty four British skulls of known or calculated age at death to evaluate the antero-posterior position of the mental foramen. The sex of the British skulls was unknown. The sample was divided into two groups above and under twenty seven years old. This study showed that there were no significant differences in the size of the Chinese and British mandibles. The most common position of the foramen in the Chinese sample was in line with the longitudinal axis of the second premolar tooth, whereas, in the British sample, it was below the space between the first and second premolar. The mean distances of the mental foramen from the symphysis menti was 27.6 (± 1.6) mm and 25.9 (± 2.0) mm in the Chinese and British skulls respectively with statistically significant differences and from the posterior border of the ramus was 70.8 mm and 71.2 mm in the Chinese and British skulls respectively. The foraminal position apparently moved distally in both groups with age and this was likely to be associated with mesial tooth drift and age-related attrition.

Mwaniki and Hassanali (1992) reported that seventy nine adult Kenyan mandibles were studied to locate the mental foramen. The sex and the age at death were not reported. The result showed 56.1% of the mental foramina were located below the second premolar while 31.1% were between the second premolar and first molar. The mental foramen opened postero-superiorly in 72.5% of the surfaces.

Shankland (1994) investigated a sample of sub-continental Indians of unknown age or sex, the sample being made up of one hundred and thirty eight mandibular sides. This study revealed that the position of the mental foramen was located directly below the second premolar in 75.36% of cases. In addition, 6.62% of the mandibles had accessory mental foramina.

Chung *et al.*(1995) reported on the locational relationship of the supraorbital foramen, infraorbital foramen, and mental foramina from photographs of one hundred and twenty four Korean skulls, thirty five males, eighteen females, and seventy one of unknown sexes. The age at death of skulls ranged from eighteen to ninety years with a mean of 65.4 years. The mental foramen most commonly was on the sagittal plane passing through the supraorbital foramen in 69.3%, whereas, in 21.8% were lateral and 9.0% medial to this plane. The supraorbital, infraorbital, and mental foramina were on the same sagittal plane in 38.1% of the cases. The mean distance of the centre of the mental foramen from the symphysis menti was 24.4 mm with no significant differences between sexes, and from the inferior border of the mandible were 15.5 mm in males and 14.0 mm in females with some difference between sexes.

Ikiz and Erem (1997) reported on fifty mandibles of unknown age belonging to the Byzantium period in order to determine population differences in localization of the mental foramen with reference to the mandibular teeth. Most of the mandibles were Alpine's and a few of them were Mediterranean subraces. Only adult males that had a complete dentition free of proximal caries and proximal attrition were used. The modal position of the mental foramen was below the space between the first and second lower teeth on the right side in 50% of cases, whereas, the modal position on the left side was in line along the lower second premolar tooth in 46% of cases.

Mbajiorgu *et al.*(1998) described the position of the mental foramen using thirty two mandibles derived from adult Black Zimbabweans of unknown age and sex. The position of the mental foramen was most frequently located below the lower second premolar tooth on the right side and posterior to it on the left side. In the vertical plane, the mental foramen lay slightly below the midpoint of the distance between the lower border of the mandible and the alveolar margin in 44.1% on the right and

45.5% on left sides respectively. In the horizontal plane, the mental foramen was situated approximately one quarter of the distance between the mandibular symphysis and the posterior border of the ramus of the mandible with 27.3% on the right and 27.4% on the left sides. The authors concluded that the location of the mental foramen in Black Zimbabweans, in relation to lower teeth, was at variance with other population groups, and that this should be considered when undertaking surgical anaesthetic procedures.

Sawyer *et al.*(1998) reported on the frequency of accessory mental foramina in four population groups there being two hundred and thirty four of 20th century Asian Indians mandibles, fifty adult Nazca mandibles, one hundred sixty six adult African Americans mandibles and two hundred and fifty five adult American Whites mandibles. The age at death was unknown. The frequency of accessory mental foramina was found less in the American White and Asian Indian populations than in the other groups. It was concluded that there was no significant difference between right and left hand sides. In African American, accessory mental foramina occur more often in males.

Berge and Bergman (2001) noted the position and bilateral symmetry of the mental foramina in a hundred randomly selected skulls. The age, sex and ethnic group of samples were not identified. The mean size of the foramen was 2.43 x 1.76 mm. There were no significant differences between the mean size of the mental foramen on the right and left sides. The result found, only 1% of the mental foramina had double openings and another 1% had triple openings.

Hanihara and Ishida (2001) investigated the accessory mental foramen on eighty one human populations from around the world. The age at death was not reported. A significant asymmetry occurred with regard to accessory mental foramina, which were more predominant in males. This study concluded that the highest frequencies of accessory mental foramina occurred in Central Asian and Sub-Saharan African samples.

Kieser *et al.*(2002) investigated the path of emergence of the mental nerve in a number of human population groups. The sample was made up of one hundred and seventeen Black African skulls of fifty three males and sixty four females, one hundred and eleven Caucasoid skulls of sixty males and fifty one females and one hundred pre-contact Maori skulls of seventy males and thirty females. In each case, the path of emergence was classified as either posterior, anterior, right-angled or multiple. The most common pattern of emergence in Caucasoids and Maoris was a posterior direction in 86.7% males and 90.2% females of Caucasoid and in 85.5% males and 93.1% females of Maori. Whereas, in the Black African group, this was a right-angled path of emergence with 45.8% of males and 45.0% of females, there being statistically significant difference between population groups. Multiple foramina were rare, with the highest incidence being in Maori and Black African males. It was concluded that the nerve's emergence might be genetically, rather than functionally determined.

Oguz and Bozkir (2002) used both right and left sides of each of thirty four young Turkish adult human male mandibles to determine the precise position of the mental foramen in relation to the surrounding anatomic landmarks. These samples were aged between 30-40 years old. The mean distances of the mental foramen from the inferior border of the mandible were 14.61 mm on the right and 14.29 mm on left sides and from the superior border of the mandible were 13.62 mm on the right and 14.62 mm on left side. The mental foramen was situated in line along the longitudinal axis of the second premolar in 61.76% on the right and 50% on left. However, it was below the space between the first and second premolars in 38.2% on the right and 50% on left sides.

Aktekin *et al*.(2003) stated that the position of the mental foramen was studied in fifty eight adult Turkish skulls of unknown sex. Based on the age, these skulls were divided into two groups. The most common position of the mental foramen was below the space between the first and second premolars. The distances of the mental foramen from the mandibular symphysis and the inferior border of the mandible were measured. With regard to these distances, the study found there were significant differences between the two groups.

Roopa *et al.*(2003) reported that one hundred and forty two South Indian mandibles of unknown sex and age were examined to assess the variations in location of the mental foramen. Accessory mental foramina were also assessed.

Olasoji *et al*. (2004) examined thirty two mandibles from Nigerian (African) adults to locate of the mental foramen. The modal location was in line with the apex of the second premolars in 35.9% and in line with the interdental space between the first and second mandibular premolars in 32.8% of cases. There were no significant differences between both sexes with regard to the position of the foramen. The quantitative position was found to be bilaterally symmetrical in most cases. They concluded that there is almost an equal chance of locating the mental foramen between the mandibular premolars or below the apex of the mandibular second premolar.

Smajilagic and Dilberovic (2004) studied the location of the mental foramen on twenty mandibles with complete dentition and intact alveolar ridge. The study revealed that the most common position of the mental foramen was in line with the longitudinal axis of the second premolar. The mean distances between the mental foramen and the midline were 25 mm. In the vertical plane, the mental foramen was at the midpoint of the distance between the lower border of the mandible and the alveolar margin, whereas, in the horizontal plane, the mental foramen was located approximately one third of the distance from the mandibular symphysis to the posterior border of the ramus of the mandible.

Souaga *et al.*(2004) studied the position of the mental foramen on sixty one Black, Ivory Coast Africans adult mandibles. In the male mandibles, the distance of the mental foramen from the symphysis was 27.31 mm, from the posterior border of the ramus was 74.75 mm, from lower border of the mandible was 14.89 mm and from the alveolar margin was 16.16 mm. However, in the female mandibles, there were 27.16 mm, 69.10 mm, 14.21 mm and 15.66 mm respectively. This study confirmed that in the horizontal plane, the mental foramen was situated approximately one quarter of the distance from mandibular symphysis to the posterior border of the ramus. The mean sizes of the long and short axes of foramina were 5.03 mm and

3.97 mm in the male mandibles, and 4.99 mm and 3.87 mm in the female mandibles respectively.

Agthong *et al*.(2005) studied one hundred and ten adult skulls. Sex was determined and recorded as seventy males and forty females. The distances from the mental foramina to midline and to the inferior border of the mandible were measured bilaterally. The mean distances from the mental foramina to the midline were 28.0 (± 0.2) mm on the right and 27.8 (± 0.2) mm on left side. The mean distances from the mental foramina to the inferior border of the mandible were 14.5(± 0.2) mm and 14.4 (± 0.1) mm on the right and left sides respectively. With regard to these measurements, there were no significant differences between both sides.

Ari *et al*.(2005) studied the location and anthropometric characteristics of the mental foramen in thirty six adult male mandibles of the Late Byzantine period. The results demonstrated that the most modal of the mental foramen was in line with the longitudinal axis of the second premolar in 50% and 47% in right and left sides respectively, followed by a location along the space between the first and second premolars in 33% and 36% on the right and left sides of cases. The results suggested that characteristics such as the localization of mental foramen may not only differ between populations of different geographic environment but also within the populations of the same geographical area.

Igbigbi and Lebona (2005) reported on the position and dimensions of the mental foramen from seventy adult indigenous Malawian mandibles of both sexes. The most common position of the foramen in related to the mandibular teeth was below the second premolar tooth. Its vertical position was slightly below the midpoint of the distance between the lower border of the mandible and the alveolar margin.

Apinhasmit *et al*.(2006) investigated one hundred and six Thai adult skulls there being sixty seven males and thirty nine females to determine the locations of the mental foramen. The age of the skulls ranged between 18 and 83 years old. There was no significant difference between the ages of sexes. The mean distance from the centre of the mental foramen to the symphysis menti was 28.52 (± 2.15) mm. There were significant differences with regard s to all measurements between sexes; the measurements in males were longer than in females. Whereas, there were no significant differences between sides except that the right mental foramen was situated more laterally than the left mental foramen. The modal position of the foramen was observed in line with the second lower premolar followed by the space between the first and second premolars. There was sex difference with regard to distribution of the foramen position. In 57.3% of cases the mental foramen was situated lateral to the sagittal plane passing through the supraorbital foramen and in 23.4% of the total subjects, the supraorbital, infraorbital and mental foramina were situated on the same sagittal plane. The direction of the mental foramen opening was usually in a postero-superior direction.

Apinhasmit *et al.*(2006) assessed sixty nine adult mandibles of forty five males and twenty four females, of Thai skulls to determine the location of the mental foramen related to sex and side. The age of the samples ranged between 18 and 83 years old. The results showed that the modal position of the mental foramen was bilaterally symmetrical and positioned along the lower second premolar. The mean distances of the mental foramen from the symphysis menti, from the posterior border of the mandibular ramus, from the lower border of the mandible and from the buccal cusp tip of the second premolar were 28.83 mm, 68.85 mm, 14.88 mm, and 24.27 mm, respectively. Sex differences were significant in all measurements. The result revealed that there were no significant differences with regard to the size of the mandible and all measurements between sides, but were significantly longer in males than in females.

Captier *et al.*(2006) studied eighty three human mandibles there being sixty dentate and twenty three edentulous. The age, sex and ethnic group of the samples were unknown. The position of the mental foramen was determined bilaterally. The mean distances between the two mental foramina was 43.8 (± 3.2) mm. The mean distances from centre of the mental foramen to the symphysis menti was 26.05 (± 1.95) mm, posterior border of the ramus was 73.84 (± 4.62) mm, inferior border of the mandible was 13.74 (± 1.52) mm and the head of condyle was 98.09 (±4.25) mm on the right side and on the left side was 26.10 (± 2.02) mm, 74.16 (± 4.61) mm, 13.75 (± 1.66) mm and 98.16 (±4.18) respectively. The study concluded that the location of the mental foramen and the mandible angle were symmetric in each group. The overall measurements related to the mental foramen were greater on the left side; however, the absolute difference between the two sides was low and mainly not clinically relevant.

Prabodha and Nanayakkara (2006) carried out a study on twenty four Sri Lankan hemi mandibles, to determine the location of the mental foramen. There were fifteen male and nine female subjects. The age ranged from 47 years to 103 years old. The measurements were obtained by using a vernier calliper. The mean distances from the mental foramen to the symphysis menti, posterior border of the ramus, and inferior border of the body of the mandible were 26.52 mm, 65.38 mm and 12.25 mm respectively. This study stated that the modal position of the mental foramen was located below the apex of the second premolar (75%) followed by a location between the first and the second premolar tooth (25%).

Fabian (2007) reported that the location of the mental foramen from a hundred mandibles of adult black male Tanzanians. The location of the mental foramen was determined in relation to the mandibular teeth. The mental foramen was located in most cases either below the apices of the second premolar or more posteriorly. The most common position of the mental foramen was in line with the longitudinal axis of the second premolar tooth in 45% of cases, followed by below the space between the second premolar and the first molar in 35% of cases. In 78% of the mandibles, the right / left side location of the mental foramen was asymmetrical. The direction of the mental foramen opening was mainly superiorly in 44% and postero-superiorly in 40% of cases.

Amorim *et al.*(2008) stated that the position of the mental foramen in a sample of one hundred and seventy Brazilian adult dry mandibles there being one hundred and eighteen males and fifty two females. Ninety one were dentate and seventy nine edentulous. The assessment was made, in relationship to the base of the mandible and the symphysis menti. The position of the mental foramen was recorded with respect to sex, contralateral position, and dentition (dentate or edentulous). The age at death was not identified. The result showed that the distances between the mental foramen and symphysis menti and base of the mandible were larger in male and dentate mandibles than in female and edentulous mandibles. The distances from the mental foramen to the symphysis menti in edentulous females on the right and left sides were 26.9 (± 0.30) mm and 26.6 (± 0.44) mm and dentate females were 27.3 (± 0.42) mm and 27.2 (± 0.46) mm respectively. In edentulous males on the right and left sides were 27.7 (± 0.33) mm and 27.5 (± 0.33) mm and dentate males were 28.9 (± 0.23) mm and 28.9 (± 0.22) mm respectively. The distances from the mental foramen to the inferior border of the mandible in edentulous females on the right and left sides were 13.5 (± 0.31) mm and 13.7 (± 0.32) mm and dentate females were 14.2 (± 0.41) mm and 14.2 (± 0.39) mm respectively. In edentulous males on the right and left sides were 13.3 (± 0.23) mm and 13.7 (± 0.21) mm and dentate males were 14.2 (± 0.21) mm and 14.2 (± 0.22) mm respectively. However, there was no difference between left and right sides in any of the groups. The most frequent position of the mental foramen was in the long axes of the second premolar for males and females. There were no statistical differences between right and left sides, comparing male to female. It was concluded the position of the mental foramen is mainly altered in edentulous subjects as it is consider a symmetric structure in Brazilian population and its most common position is in the long axes of the second premolar.

Gupta (2008) determined the position of the mental foramen in seventy nine North-West Indian adult dried human skulls of unknown sex and age. The mean distances from the mental foramen to the midline were 25.8 mm and similar on both sides demonstrating facial symmetry. The mean distance from the mental foramen to the inferior mandibular margin was 13.2 mm and the mean distance between the mental foramen on both sides was 43.6 (± 7.7) mm. In more than 80%, the supraorbital, infraorbital and mental foramina were in same sagittal plane. Both the infraorbital and mental foramina were most often on a vertical line with the second premolar.

Yesilyurt *et al.*(2008) determined the position of the mental foramen in different population groups. Seventy adult mandibles from a Turkish population (Eastern Anatolian population) of unknown age and sex were investigated. The most common position of the foramen was along the axis of the second premolar tooth in 55.7% on the right and in 61.4% on the left side. The mean distances from the alveolar crest to the lower border of the mandible crossing the mental foramen was 19.94 mm on the right side and on the left side was 20.10 mm, the distance from the inferior border of the foramen to the lower border of the mandible was 9.44 mm and 9.46 mm respectively, in other words, at the midpoint of the mandibular body height. Also the mental foramen was found at 1:3.5 of the distance from the symphysis menti to the posterior border of the ramus.

Oliveira *et al.*(2009) determined the location of the mental on eighty mandibles of unknown sex and ethnic group. Only adult mandibles were used in this study. The mean distances, from the inferior margin of the mental foramen to the inferior border of the mandible was 12.96 (± 1.57) mm on the right side and on the left side was 12.96 (± 1.32) mm and from the superior margin of the mental foramen to the alveolar ridge were 12.82(± 3.4) mm and 12.82 (± 3.22) mm respectively. The location of the mental foramen related to the mandibular dentition on the right side was localized in similar statistic proportions between the first and second premolars and below the second premolar, in 45.17% of the mandibles. On the left side it was predominantly found between the first and second premolars with 48.48% of the mandibles.

Lopes *et al.*(2010) analysed variations in the mental foramen position in eighty adult mandibles in Southern Brazil. The sex and the age at death were not reported. The distances from the centre of the mental foramen, to the sagittal midline was 25.98 (± 2.19) mm on the right side and 26.30 (± 2.41) mm on the left side, to the lower border of the mandible was 14.12 (± 1.80) mm and 13.55 (± 1.94) mm respectively. The modal position of the mental foramen in related to the mandibular teeth was posterior to the first premolar and the frequency of the double mental foramina was 7.5% on the right side and 3.8% on the left side of cases. With regard to the distance between the foramen and the midline there was no significant difference between the right and left sides, whereas, there was a significant difference with regard to the distance from the foramen to the lower border of the mandible between sides, greater on the right side.

Agarwal & Gupta (2011) studied the morphological features and position of the mental foramen related to surrounding anatomical landmarks in an adult South

Gujarat population, using a hundred human mandibles. The sex was unknown. The mental foramen was positioned below the second premolar tooth in 81.55% on the right side and 81.50% on the left side. The direction of the foramen opening was in a postero-superior direction in 92%. The mean distances found on the right and left respectively, from the mental foramen to symphysis menti were 25.55 (± 5.07) mm and 25.05 (± 5.07) mm, to the alveolar margin were 14.05 (± 3.05) mm and 13.82 (± 3.06) mm, and to the inferior border of the mandible were 12.16 (± 3.04) mm and 12.11 (± 3.11) mm respectively.

Chrcanovic *et al*. (2011) studied the different morphometric variations of the human mandibles, comparing male and female dentate and edentulous mandibles. Eighty adult human mandibles of unknown age were studied. The mandibles consisted of urban and rural individuals from the Brazilian state of Mina Gerais belonging to the twentieth century. There were sixty four dentate mandibles forty six females and eighteen males and sixteen edentulous mandibles, nine females and seven males. All measurements were taken bilaterally, using a digital calliper, millimetre ruler. The study showed that the position and anatomical relations of the mental foramen and overall dimensions of the mandible are particularly influenced by dental status. In the comparison between males and females, only a few measurements were statistically significantly different. It was concluded that the difference in sex has a lower influence on the mandibular anatomy than the dental status.

Sankar *et al*.(2011) examined ninety dentulous mandibles of both sexes of a South Andhra population of India to determine the morphometry and morphology of the mental foramen using Vernier calliper. The mean horizontal distances of the anterior margin mental foramen from the symphysis menti were 27.2 mm on the right and 27.7 mm on left side and from the posterior border of the ramus was 70.7 mm on both sides. The mean vertical distances from the inferior border of the mental foramen to the inferior border of the mandible were16.5 mm on the right and 14.3 mm on left sides and to the alveolar crest were 13.7 mm and 16.4 mm respectively. The mean distances between the superior margin of the mental foramen and below the apex of premolar were +2.8 mm on right and +3.5 mm on left and above the socket was -2.8 mm on right and -2.7 mm on left. The modal position of the mental foramen was below the second premolar tooth in 73.2% of cases. The mean diameter sizes of the foramina were larger on left and its way of exit was in postero-superior direction.

Budhiraja *et al*.(2013) studied the morphological features and morphometric parameters of the mental foramen with regard to surrounding landmarks on one hundred and five adult human mandibles from North India of unknown sex. The position, shape and number of mental foramina were measured using a digital vernier calliper. The mental foramen was situated in line along the second premolar tooth in 61% on the right side and 59.1% on the left side of all cases. The mean distances for the right and left sides, measured from medial margin of the mental foramen to symphysis menti, were 25.39 (± 0.66) mm and 25.29 (± 0.30) mm, from the lateral margin of mental foramen to posterior border of the ramus, 65.76 (± 0.70) mm and 66.13 (± 0.77) mm, from the superior margin of the mental foramen to the alveolar margin, 11.46 (± 0.25) mm and 11.33 (± 0.17) mm, and from the inferior margin of the mental foramen to the inferior border of the mandible, 15.25 (± 0.24) mm and 15.40 (± 0.22) mm.

Parmar *et al*.(2013) studied fifty adult human mandibles from Eastern Indian population with a complete dentition and intact alveolar margin of unknown sex. The morphometric measurements were taken using Vernier callipers. The modal position of the mental foramen in related to the lower teeth was below the second premolar in 64.7 % of cases on the right and 66.7 % of cases on the left side, whereas, the next common position was between the premolars in 21.6% on the right and 19.6% of cases on the left sides. The mean distances of the anterior margin of the mental foramen from the symphysis menti was 23.3 mm on the right and 22.5 mm on left sides. The mean distance of the posterior margin of the mental foramen from the posterior border of ramus was 61.3 mm and 62.5 mm on the right and left sides respectively. The mean distance of the superior margin of the mental foramen from the alveolar crest was 10.6 mm on the right and 10.3 mm on the left side. The mean distance of the inferior margin of the mental foramen from lower border of the body of mandible was 10.7 mm on the right and 10.7 mm on the left side.

2.3.2 Papers Related to Studies Using Radiography

Fishel *et al.*(1976) examined “1000” full mouth intraoral radiographs to evaluate the location of the mental foramen. The mental foramen was identified in only 936 (46.8%) of the 2000 sides examined, 482 on the left side and 454 on the right side. In 30% cases the mental foramen was clearly identified bilaterally. It was identified unilaterally in 33.6% of cases. In 36.4% the mental foramen could not be identified clearly. In the horizontal plane, the position of the mental foramen was between premolars, in the apical area of the premolars and mesial or distal to the premolar area with 70%, 22% and 7.5 % of the cases respectively. In the vertical plane, the highest percentage of mental foramina was found to be located superior to the level of the apices of the premolars.

Kekere-Ekun (1989) reported that the location of the mental foramen in the horizontal plane was studied in six hundred and four oblique lateral radiographs of Nigerian mandibles. The age and sex were known. The modal position of the foramen was in line with longitudinal axis of the second premolar in 55.63 % of the radiographs, while 26.99 % occurred along the interdental space between the first and second premolars. The author concluded that the location of the mental foramen was asymmetrical in 12.3% of these patients, and more frequently in females in 53% of cases; the right foramen was located more posteriorly than the left foramen.

Kjaer (1989) investigated the formation and location of the human mental foramen in forty three human foetuses. The sex and ethnic group of the foetuses were not reported. Histochemical methods supplemented by macroscopic visualization were used. The study indicated that the position of the mental foramen in the very early period was between the primary canine and the primary first molar then it changed posteriorly during the first half of the prenatal period.

Neo (1989) determined the position of the mental foramen of Malays and Indians in Singapore of unknown age and sex from a series of orthopantomograms. The study revealed that the modal position of the mental foramen of both populations was just below the second premolar for the right and left sides.

Yosue and Brooks (1989) studied the position of the mental foramen on panoramic and periapical radiographs taken from four dry skulls of an infant, a teenager, an adult female and an adult male. The study found that any change in exposure conditions affected both appearance and the relative vertical position of the foramen. On the panoramic radiographs, the mental foramen appeared more consistently than on the periapical radiographs. The study concluded that the radiographic diameters of the mental foramina change according to the positioning of dry skulls and the angulation of x-ray equipment.

Phillips *et al*.(1992) reported on seventy five adult human skulls, radiographed with a paralleling technique to determine the size and position of the mental foramen. The age and sex of the subjects were not reported. The radiographic size of the foramen was determined and compared with values reported in other studies, and was found to be smaller than the anatomical sizes previously given. There were no significant differences in size and visualization of the mental foramina between the right and left sides. The position of the mental foramen was usually 2.18 mm mesial and 2.41 mm inferior the radiographic apex of the mandibular second premolar.

Phillips *et al*.(1992) studied the panoramic radiographs of seventy five dry adult human mandibles. The sex, age and ethnic group of the specimens were not reported. The mean of the horizontal and vertical dimension of the foramina was 2.9 mm and 2.5 mm respectively, there was no significant difference in the size between both sides. The mean position of the mental foramen was 0.13 mm mesial and 3.0 mm inferior the radiographic apex of the mandibular second premolar. The mental foramen on panographic radiographs was slightly larger than reported on periapical radiographs. The mean position of the foramen was mesial and below the radiographic apex of the tooth. The mean radiographic distance from the buccal cusp tip of the second premolar to the centre of the mental foramen was 28.0 mm and to the inferior border of the mandible was 44.1 mm. The mean ratio of these distances was 63.6% for the vertical position of the mental foramen on both sides of the mandibles.

Soikkonen *et al*.(1995) reported on a study in which the distance of the mental foramen and mandibular canal from the lower cortex of the mandible were compared in a radiographed series of forty edentulous elderly women with advanced alveolar atrophy and 40 elderly women who had 10 or more lower teeth. The ethnic group or age of patients was not reported. The study showed that the mental foramen was positioned in edentulous jaws on average 3.8 mm lower than in dentulous jaws. The authors concluded that the mental foramen seems to descend as a result of alveolar atrophy.

Al Jasser and Nwoku (1998) studied four hundred and fourteen panoramic radiographs of a Saudi population of age ranged from 14 to 64 years old to demonstrate the most common position of the mental foramen. After twelve males and five females were excluded because the mental foramen could not be identified on both sides, finally a total of three hundred and ninety seven panoramic radiographs were analysed there being two hundred and thirty five males and one hundred and sixty two females. The modal position of the mental foramen was along the longitudinal axis of the second premolar in 45.3% of cases and along the space between the first and second premolars in 42.7% of cases. The authors found that the mental foramen was symmetrical in 80% of cases.

Ngeow and Yuzawati (2003) reported on the position of the mental foramen in a selected Malay population, determined by using one hundred and sixty one panoramic radiographs of Malay patients. The age ranged from 14 to 43 years old. The most common position of the mental foramen was in line with the longitudinal axis of the second premolar in 69.2% followed by along the space between the first and second premolar in 19.6% of cases. The right and left foramina were bilaterally symmetrical in 67.7% patients.

Olasoji *et al.*(2004) reported on one hundred and fifty seven panoramic radiographs, randomly selected from Nigerian adults of known sex. The commonest position of the mental foramen was along the interdental space between the first and second mandibular premolars in 34% of the cases, followed by the position apical to the second premolars in 25.5% of the cases. There were no significant differences in the distribution between sexes and sides in most cases.

Smajilagic and Dilberovic (2004) studied the location of the mental foramen using orthopantomogram radiographs. The age, sex, and the ethnic group were not reported. The study revealed the modal position of the mental foramen was in line with the longitudinal axis of the second premolar. In the vertical plane, on the orthopantomogram, the mental foramen occurred slightly below the midpoint of the distance from the alveolar margin to the inferior border of the mandible. In the horizontal plane, the mental foramen lay approximately one third of the distance between the symphysis menti and the posterior border of the ramus of the mandible.

Gungor *et al*.(2006) reported on the most common position of the mental foramen in three hundred and sixty one panoramic radiographs of selected Turkish population there being one hundred and forty four males and two hundred and seventeen females. The patient's age ranged from 14 to 57 years old. The most common position of the mental foramen was between the first premolar and the second premolar in 71.5% of cases. The position of the mental foramen was symmetric in 85.8% of patients.

Kim *et al*.(2006) reported on one hundred and twelve mental foramina of a Korean population of seventy two males and forty females. All patients had fully erupted lower premolars, the age ranged from 12 to 69 years old. The horizontal and vertical locations were evaluated both directly and by radiographic measurements. The most common position of the mental foramen in direct and radiographic measurements was in line with the second premolar in 64.3% and 62.5% of cases respectively. The mean distances from the superior border of the mental foramen to the cusp tip by direct and the panoramic measurements were 23.42 mm and 25.69 mm respectively and to the bottom of the mandible were 14.33 mm and 16.52 mm respectively.

AL-Khateeb *et al*.(2007) conducted a study using eight hundred and sixty panoramic radiographs of Jordanians, with a female to male ratio of 1:1.4. The ages ranged from 12 to 77 years old. The modal position of the mental foramen with regard to the anterior-posterior position was along the space between the mandibular premolar teeth in 47% of cases, followed by the position along the apex of the second premolar in 40% of cases. There was a significant difference between male and female. With advancing age, there was an increase in the frequency of a more posterior and inferior positioning. With regard to the superior-inferior position, the commonest position of the mental foramen was below the level of the apices of the mandibular premolar roots, with no significant difference between the males and females. The foramen moved inferiorly with advancing age.

Dutra *et al*.(2007) took standardized panoramic radiographs from ten dried mandibles of unknown age, sex or ethnic group, and compared the measurements taken from the radiographs with those made directly from the dried mandibles. Agreement between the actual mandible measurements and the radiographic assessment was moderate for the non-corrected measurements. Agreement between anatomic and radiographic measurements improved remarkably well after standard correction for magnification.

Al Taliban *et al*.(2008) studied one hundred and sixty panoramic radiographs from both male and female Kurds of Aryan ethnic group there being one hundred and ten dentulous patients of age from 18 to 40 years and fifty edentulous patients of undetermined age. In the dentulous population, most common position of the mental foramen in relation to the mandibular teeth was in line with the longitudinal axis of the mandibular second premolar in 55% of cases, followed by in line along the space between the first and second premolars in 35.9% of cases. The positions of the mental foramen in dentulous population were predominantly bilaterally symmetrical in 82.7% of the patients. In the dentulous population, the mean distance from the centre of the foramen to the alveolar bone crest was 23.5 mm in males and 21.54 in females, to the inferior border of the mandible was 15.9 mm in males and 14.08 mm in females. In the edentulous population, the mean distance from the centre of the foramen to the superior border of the mandible was 16.92 mm in males and 14.21 mm in females, to the inferior border of the mandible was 14.40 mm in males and 13.99 mm in females. The authors concluded that the mental foramen was located slightly below the midpoint between the inferior border of the mandible and the alveolar bone crest. There were no significant differences between both sides in the same sex, whereas, the distances in males were significantly longer than in females. With regard to the distance between the foramen and the inferior border of the mandible, there were no significant differences between the dentulous and edentulous populations, but were highly significant with regard to the distance between the foramen and the alveolar bone crest.

Haghanifar and Rokouei (2009) analysed four hundred panoramic radiographs of an Iranian population there being one hundred and seventy eight males and two hundred and twenty two females of known age to demonstrate the most common location of the mental foramen. This study found that the mental foramen was situated along the space between the first and second mandibular premolars in 47.2% of patients and in line with the longitudinal axis of the second premolar in 46%. In 49.2% of males, the mental foramen was below the second premolar. In 50.9% of females the foramen was between the first and second premolars. The position of the mental foramen was symmetrical in 85.7% of cases.

Pria *et al.*(2011) evaluated five hundred digital panoramic images using only the right side of the mandible of adult dentate patients. The most frequent position of the mental foramen was along the space between the first and second mandibular premolar in 59% of cases.

Rupesh *et al.*(2011) reported on the most common position and symmetry of the mental foramen in a randomly selected Asian Indian population using digital panoramic radiographs of five hundred cases there being two hundred and fifty males and two hundred and fifty females. The age of subjects ranged from 18 to 79 years old. The results revealed that the modal position of the mental foramen relative to the teeth was in a line between the first and second premolars in 47.6% of cases. The second most common position was in line with the second premolar in 33.5% of cases. The mental foramen was symmetrical in 57%, and asymmetrical in 43% of radiographs. The study concluded that the sex and symmetry did not influence the position of the mental foramen in this population.

2.3.3 Papers Related to Studies Using Cadavers

Tebo & Telford (1950) reported on one hundred unsexed adult dentulous mandibles. The study assessed the location of the mental foramen in relation, to the lower premolar teeth, and to the body and ramus of the mandible. A calliper was used and the mandible was placed in the “Morant’ position”. The most common position of the mental foramen was in line with the longitudinal axis of the mandibular first premolar tooth in 46.0% of cases on the right and 52.8% on the left side, followed by along the space between the apices of the lower bicuspid teeth in 25.3% and 20.7% of cases respectively and posterior to the second premolar tooth in 24.1% and 24.1% of cases respectively. In the relation to the body and ramus, the distance from the most anterior point of the anterior border of the mental foramen to the symphysis menti was 26.8 (± 2.33) mm on the right and 26.6 (± 2.32) mm on the left sides, to the posterior border of the ramus was 74.6 (± 6.09) mm and 74.9 (± 5.90) mm, to the inferior border of the mandible was 15.2 (± 1.54) mm and 15.0 (± 1.57) mm respectively. The authors concluded that the mental foramen was found to lay approximately one fourth of the distance from the symphysis menti to the posterior border of the ramus.

Gershenson *et al.*(1986) pointed out that in fifty cadavers the modal position of the mental foramen in relation to the mandibular teeth was in front of the apex of the root of the second premolar in 43.66% of cases.

Wang *et al.*(1986) measured the anatomical location of each mandibular mental foramen in hundred mandibles of adult Chinese cadavers of both sexes without missing teeth. The age at death of cadavers was not reported. The most common position of the mental foramen was in line with the longitudinal axis of the apex of the mandibular second premolar in 58.98% of cases. The mean distances from the most anterior portion of the anterior border of the mental foramen to the symphysis menti was 28.06 mm, to the posterior border of the ramus was 74.14 mm, from the inferior border of the mental foramen to the inferior border of the mandibular body 14.70 mm, and from the superior border of the mental foramen to the bottom of the mandibular second premolar socket was 2.50 mm. The mean distance across the mental foramen from the alveolar crest to the inferior border of the mandible was 30.29 mm.

Moiseiwitsch (1998) studied one hundred and five human cadavers there being forty five African Americans and sixty Whites Americans. The sex was fifty one males and fifty four females. The age was not reported. The modal position of the mental foramen was on average, between the premolars. The mean vertical distance of the mental foramen from the cementoenamel junction of the nearest tooth was 16 mm.

Kieser *et al*.(2002) reported on the path of emergence of the mental nerve in fifty six cadaveric human mandibles of Caucasoid population there being twenty six males and thirty females. The cadaveric mandibles were examined and an osteotomy of 1 cm was made on either side of the mental foramen to expose the nerve. In each case, the path of emergence was classified into posterior, anterior, right-angled or multiple. The study showed that the dominant pattern of the mental nerve was posteriorly directed emergence in 80.7% of males and in 86.6% of females.

Cutright *et al*.(2003) evaluated the position of the mental foramina in eighty cadavers there being twenty white males, twenty black males, twenty white females, and twenty black females. The age at death of the cadavers was not reported. The mean distances for all race and sex groups from the centre of the mental foramen to the mandibular midline was 22 mm, in white males, black males, white females and black females, 22.5 (± 0.4) mm, 22.9 (± 0.6) mm, 20.5 (± 0.4) mm and 21.9 (± 0.4) mm respectively. In relation to the mandibular teeth, the most common position of the mental foramen was positioned more posterior in blacks than in whites, in whites, it was positioned between the first and second premolars, whereas, just posterior to the second premolar in blacks.

Neiva *et al*.(2004) analysed the position of the mental foramen in relation to other known anatomical landmarks in twenty two Caucasian skulls of known age and sex. The study showed the mean distances of the mental foramen from the cementoenamel junction, inferior border of the mandible, midline, and from mental foramen to mental foramen were 15.52 (±2.37) mm, 12.0 (± 1.67) mm, 27.61(± 2.29) mm, and 55.23 (± 5.34) mm respectively.

Song *et al.*(2007) investigated fifty embalmed cadavers of Koreans. The age and the sex were not reported. The mean distances between the mental foramina and the corners of the mouth (cheilions) were measured directly on the cadavers, the vertical and horizontal distances between the mental foramen and infraorbital foramen and the cheilions, respectively, were measured indirectly on photographs. The mental foramen was situated inferior and medial to the cheilions with measured distances of 20.4 (± 3.9) mm and 3.3 (± 2.9) mm respectively. The mean distance between the cheilions and mental foramen was 20.9 (± 3.8) mm and the vertical angle between these structures was 9.2 (± 8.1) degrees inferomedially.

Hur *et al.*(2008) demonstrated the topographical anatomy between the depressor anguli oris and the mental foramen. Thirty four hemi-faces of seventeen Korean adult cadavers of eight men and nine women were evaluated. The mean age at death of the cadavers was 71 years old. Vertically, the mental foramen was positioned in the middle third from the cheilion to the mandibular border in 90.3% of cases, whereas, in horizontal relationship, the foramen was mostly situated within the depressor anguli oris muscle coverage in 67.7% of cases, followed beneath the depressor labii inferioris muscle medial to the medial border of the depressor anguli oris in 22.6% of cases.

Guo *et al.*(2009) dissected twenty one adult Chinese cadavers there being sixteen men and five women, to evaluate the mental foramen. The cadavers were aged at death from 30 to 75 years. The position of the mental foramina was evaluated using both direct and photographic measurements. In the front view, the mental foramina was situated 23.38 (± 2.00) mm inferior and 3.55 (± 1.70) mm medial to the cheilion, whereas, in the lateral view this was 23.59 (± 2.11) mm inferior and 7.19 (± 3.03) mm posterior to the cheilion. Related to the hard-tissue landmarks, the modal position of the mental foramen was positioned along the second premolar in 73.8% of cases, and the mean distance of the mental foramen below the cusp tip of the second premolar was 23.34 (± 2.39) mm, below the inferior alveoli was 16.56 (±2.53) mm, and superior to the bottom of the mandible was 15.56(± 1.74) mm.

Smith *et al.* (2010) studied fourteen Caucasian cadavers there being six males and eight females aged from 46 to 88 years. The position of the mental foramen was evaluated using a digital calliper. The mean distances of the mental foramen from the angle of the mandible was 64.2 (± 6.4) mm and from the inferior border of the mandible was 12.9 (± 1.6) mm. The study concluded that these results may be useful in positioning of the mental foramen using palpable landmarks particularly for surgery in edentulous patients or who had dentures, especially in cases where there were fractures of the maxillary bone.

Kqiku *et al*.(2011) studied four hundred human cadaver specimens to evaluate the position of the mental foramen. The most common position of the mental foramen was along the space between the first and second mandibular premolars.

2.3.4 Papers Related to Studies Using Scanning Methods

Katakami *et al*.(2008) studied the anatomic characteristics of the accessory mental foramina and accessory branches of the mandibular canal using limited cone-beam computed tomography of one hundred and fifty patients. In sixteen patients, seventeen accessory mental foramina were found. The age, region and sex of the patient were not reported. The mean horizontal and vertical diameters of the mental foramen were 3.5 mm and 2.6 mm respectively. The study showed that most common position of the mental foramen was in apical of the mandibular second premolar, meanwhile, the most common position of the accessory mental foramina was in the apical area of the first molar. The common characteristics of the accessory branches of the mandibular canal tended to be in the course of gently sloping postero-superior direction in the buccal surface area. The authors concluded that the knowing of the position of accessory mental foramina would prevent accessory nerve injury during periapical surgery.

Periago *et al*.(2008) compared the accuracy of linear measurements made on cone beam computed tomographic to direct measurements made on 23 human skulls using a digital calliper. The study showed that cone beam computed tomographic measurements were statistically significantly different from the measurements made directly on anatomic specimens. This statistical significance probably does not translate into clinical relevance.

Naitoh *et al*.(2009) evaluated one hundred and fifty seven patients, forty eight males and one hundred and nine females, to assess the mental and accessory mental foramina using cone-beam computed tomography images. The mean age was 51.5 years ranged from 17 to 77 years old. An accessory mental foramen was observed in 7% of patients, and the mean distance between the mental and accessory mental foramina was 6.3 (± 1.5) mm.

Peker *et al*.(2009) used six edentulous human mandibles to compare the efficiency of conventional and digital panoramic images for localization of mental foramen. In this study, the vertical and horizontal measurements were performed on conventional and digital panoramic radiographs. Also the correlations between conventional and digital radiographic and direct measurements were compared using Pearson correlation coefficient, t-test. Generally, the results found that the measurement errors in conventional panoramic radiography were less than in digital radiography. Statistically, there was strong positive correlation between direct and radiographic measurements. This study revealed that diagnostic performance of conventional and digital panoramic radiographs appears to be equal for the localization of mental foramen.

Angel *et al*.(2011) studied one hundred and sixty five dentate adult patients there being one hundred and ten females and fifty five males with an age range of 18 to 80 years old. The position of the mental foramen in cone-beam computed tomography was determined with respect to age and sex. The position of the mental foramen and the inferior alveolar canal were assessed in coronal view. The result showed no statistical significance difference in the relative position of the inferior alveolar canal and mental foramen with regard to the effects of age and sex.

Fuakami *et al*.(2011) investigated the buccal perimandibular neurovascularisation associated with the mandibular accessory buccal foramina using a limited cone-beam computed tomography. In this study, five Japanese cadaveric mandibles were examined using helical CT to assess the presence or absence of accessory buccal foramina. Two of the five mandibles of 60 years old woman and 30 years old man which were suspected of having accessory buccal foramina were subjected to limited cone-beam computed tomography. The results found 4 accessory buccal foramina had different perimandibular neurovascularisation. Only one accessory foramen was associated with a branch of the mental nerve which re-entered the mandible through the accessory foramen after it exited from a mental foramen. Three other accessory foramina were associated with a branch of the submental artery, facial artery and buccal artery. It is concluded that it is useful to use cone-beam computed tomography for pre-operative three-dimensional assessment of the mandible since high resolution analysis provides not only an image of the skeletal conditions but also indicates the sites of entry of the vessels and nerves.

Kalender *et al*. (2011) reported that the occurrence and position of the mental foramen and accessory mental foramina in Turkish patients using cone-beam computed tomography with 3D imaging software. Scans of three hundred and eighty six sites in one hundred and ninety three patients of ninety two male, one hundred and one female with an age range between 20 and 83 years were analysed. Distances from both foramina to the alveolar ridge and to the closest tooth and between the mental foramen and accessory mental foramen were measured. Differences in accessory mental foramina incidence by sex, side and location were evaluated. The results recorded accessory mental foramina in 6.5% of patients.

2.4 Mandibular Foramen

2.4.1 Papers Related to Studies Using Dry Skulls

Hayward *et al*.(1977) examined one hundred and seven intact human skulls with mandibles, there being forty five Asiatic and sixty two mixed skulls of black and white cohorts. The skulls were all adult as judged by dental age. The position of the mandibular foramen on the skulls was assessed using a calliper. In the Asiatic group, the mean distance from the anterior border of the mandibular foramen to the anterior border of the ramus was 15.67 mm on the right side and 15.73 mm on the left side and to the posterior border of the ramus were 15.14 mm and 14.27 mm respectively. In the American group, the mean distance from the anterior border of the right mandibular foramen to the anterior border of the ramus was 15.21 mm and to the posterior border of the ramus was 15.04 mm. The mandibular foramen was found to be located in the third quadrant antero-posteriorly. The lingula was located just anterior to the mandibular foramen. There was no right- or left-side dominance in the ramus size and position of the mandibular foramen. There was no significant difference noted in the location of mandibular foramen in the two groups studied.

Nicholson (1985) examined eighty adult human mandibles on East Indian population, with bilateral eruption of third molar teeth, to measure the position of the mandibular foramen using a Micropol Universal calliper compass. The foramen was mostly situated halfway along the distances between the anterior and posterior border of the ramus and between the mandibular notch and the inferior border of the mandible and two thirds of the way along a line joining the coronoid process to the angle of the mandible. Most mandibular foramina were situated below the occlusal surfaces of the molar teeth in 75% of cases and at the same level in 22.5% of cases.

Hetson *et al*.(1988) studied three hundred and seventeen hemisected human mandibles. The position of the mandibular foramen was positioned by using the narrowest antero-posterior width of the ramus and the gonial angle as the important parameters. The mean value of the narrowest antero-posterior width of the ramus was 30.4 mm and the distance between the foramen and the narrowest width of the ramus was 4.8 mm, whereas, the gonial angle degrees was 123°. The authors concluded that the most common position of the mandibular foramen was just posterior the middle of the ramus. The more obtuse gonial angle suggests an expanded growth potential of the mandible.

Mwaniki and Hassanali (1992) examined seventy nine adult African mandibles. The most common position of mandibular foramina was below the level of the posterior extension of the occlusal plane in 64.6% of cases, while it was situated along the occlusal plane in 30.7% of cases.

Kaffe *et al*. (1994) took direct measurements of one hundred human dentulous adult mandibles and repeated these two different panoramic radiographic machines. The measurements obtained from the panoramic radiographs and the same distances measured on the same dry mandibles were compared statistically with Pearson's correlation coefficient test. The correlations between the distances on the dry mandibles were similar to the correlations between the distances using both panoramic machines. A linear logistic regression equation was developed that could predict the actual location of the mandibular foramen from the radiographs.

KerosNaglic *et al*.(1997) reported on the position of the mandibular foramen from macerated skulls. In the antero-posterior direction, the mandibular foramen was situated precisely in the middle of the distance between the anterior border and the posterior border of the ramus. In the vertical direction the lowest point of mandibular foramen was slightly closer to the mandibular angle than to the mandibular notch.

Jerolimov *et al.*(1998) studied one hundred mandibles of a Croatian population to evaluate the morphological variations and topography of the mandibular foramen using an electron gliding ruler and goniometer. The measurements were taken in antero-posterior and infra-superior directions. In the anterior-posterior direction, the mean distance from the lowest point of the mandibular foramen to posterior border of the ramus was 15.03 mm, to anterior ridge of the ramus was 17.52 mm, and to the crista temporalis was 14.81 mm. In the infra-superior direction, the mean distances from mandibular foramen to the mandibular angle was 21.10 mm, to the mandibular notch 25.19 mm, to condylar process 44.17 mm, and to the coronoid process 42.79 mm. The mandibular foramen was positioned at the juncture of the anterior two thirds and the posterior third of the ramus of the mandible. In the infra-superior direction the lowest point of the mandibular foramen was situated closer to mandibular angle than to the mandibular notch, indicating a somewhat lower position of mandibular foramen.

Mbajiorgu (2000) studied thirty eight dry mandibles from adult black Zimbabweans to determine the position of the mental foramen. The mean position of the mandibular foramen was behind the midpoint of the rameal width at about 2.56 mm on the right and 2.08 mm on the left sides and at approximately 3 mm superior to the midpoint of the rameal height on both sides. The mean anterior and posterior rameal widths were respectively 18.95 (± 0.41) mm and 14.30 (± 0.35) mm, while the mean rameal heights were 22.50 (± 0.50) mm and 28.44 (± 0.65) mm. The most common position of the foramen was on the same level with the occlusal plane in 47.1%, above the plane in 29.4%, and below the plane in 23.5% of the cases.

da Fontoura *et al*.(2002) evaluated two hundred and eighty dry adult human mandibles directly and via panoramic radiography to obtain the horizontal and vertical positions of the mandibular foramen in the ramus. The measurements of dry mandibles and the panoramic radiography were compared. The mandibular foramen was situated approximately at the posterior third of the ramus, in both the vertical and horizontal directions. The mandibular foramen was positioned within 7 mm of the posterior edge of the mandible in only 3.3% of cases.

Oguz and Bozkir (2002) used both right and left sides of each of thirty four dried young Turkish adult skulls of age ranging between 30 and 40 years old, to determine the position of the mandibular foramina. The mandibular foramen was situated posterior to the centre of the ramus on the right and on the left respectively with 0.5 mm and 0.75 mm in most cases. The distance from the mandibular foramen to the lowest point of mandibular notch was 22.37 mm on the right side and on the left sides was 22.17 mm.

Huang (2003) studied one hundred and fifty three adult mandibles of seventy four males and seventy nine females from Shanghai, China to determine the position of the mandibular foramen. Vertically, the mean distances from the centre of mandibular foramen to the lowest point of mandibular notch was 24.50 mm in males and 23.13 mm in females. Horizontally, the mean distance to the posterior border of the ramus was 16.75 mm and 16.08 mm respectively. The mean width and depth of the mandibular notch was 34.20 mm, 15.33 mm in males and 32.69 mm, 14.49 mm in females respectively. The author concluded that there were no significant differences between male and female adults with regard to all these distances.

Kilarkaje *et al.*(2005) studied one hundred and thirty two dry mandibles there being eight young, ninety three adult and thirty one old mandibles. The sex and ethnic group of the specimens were unknown. The distances from the centre of the mandibular foramen to the head of the mandible, to the third molar, to the anterior border of the ramus, to the mandibular notch, to the angle of mandible, and to the symphysis menti were measured. The results showed the mandibular foramen was situated approximately 25 mm from the third molar, the anterior border of the ramus, the mandibular notch and the angle of mandible. The study revealed that the distances between the mandibular foramen and other landmarks gradually increased with advancing age. However, within each group, the mandibular foramen was situated at the same distances from each landmark on both sides indicating symmetry. It was concluded that the location of the mandibular foramen maintains absolute bilateral symmetry in human mandibles, regardless of age.

Captier *et al*.(2006) studied eighty three dry human mandibles there being twenty three dentate and sixty edentulous mandibles to determine the position of mandibular foramen bilaterally in relation to the mandibular notch. The sex and ethnic group of the specimens were unknown. The distances from the mandibular foramen to the posterior border of the ramus, to the pre-angular notch, to the head of the mandible, to the mandibular notch and to the superior genial spine were measured. The position of the mandibular foramen was symmetric except for the distance from the mandibular foramen to the mandibular notch which was larger on the right side than left side. The symmetry was not modified by the dental status.

Fabian (2006) evaluated fifty adult black Tanzanian mandibles to describe the location of the lingula in relation to the mandibular foramen, and the location of the mylohyoid groove in relation to the lingula and mandibular foramen. The lingula was located anterior or posterior to the mandibular foramen. The mylohyoid groove originated from the medial wall of the mandibular foramen at the posterior border of the lingula in 64% of the mandibles; the mylohyoid groove started on medial wall of the mandibular foramen, unrelated to the lingual in 24% and at the posterior border of the mandibular foramen in 12% of mandibles. The author concluded that in more than half of the adult mandibles the lingula contributes to the formation of the anterior half to two thirds of the medial wall of the mandibular foramen and the mylohyoid groove starts at the posterior border of the lingula. In less than half of the adult mandibles the mylohyoid groove was unrelated to the lingula starting at the posterior one third of the medial wall or at the posterior border of the mandibular foramen.

Kositbowornchai *et al*.(2007) studied seventy dry adult mandibles there being fifty two males and twenty females of Thai origin, the age ranged between 27 to 87 years old. The accuracy of measurements made using panoramic radiograph and those made with digital callipers were compared. Only twenty three dry mandibles were dentate there being nineteen males and four females of age ranging from 24 to74 years of age. The study showed that there were significant differences between the mean measurements made from panoramic radiographs and dry mandibles.

2.4.2 Papers Related to Studies Using Radiography

Hwang *et al*. (1990) studied one hundred and twelve males and females children and adult patients, to evaluate the changes in the position of the mandibular foramen with age. Lateral cephalometric radiographs were randomly selected according to age. The mandibular foramen was situated 4.12 mm below the occlusal plane at the age of 3 years. Subsequently, the foramen moved upward with age. By the age of 9 years, the foramen was approximately at the level of the occlusal plane. The foramen continued to move upward to 4.16 mm above the occlusal plane in the adult group. The mean vertical position of the foramen moved from the lower third of the ramus in the 3 year-old group to the middle of the ramus in adults.

Afsar *et al*.(1998) examined seventy nine panoramic radiographs and seventy corresponding cases of oblique cephalometric radiographs to assess the position of the mandibular foramen. The results showed that the position of the mandibular foramen was highly individualistic and not consistently related to traditional clinical landmarks. There were no significant differences between the measurements obtained from the two types of radiographs. The study concluded that the relationship of the mandibular foramen to bony landmarks is highly variable.

da Fontoura *et al*.(2002) studied two hundred and eighty dry adult human mandibular rami, using panoramic radiography, to obtain the horizontal and vertical positions of the mandibular foramen in the mandibular ramus. In both the vertical and horizontal directions, the modal position of the mandibular foramen was approximately at the posterior third of the ramus. The mandibular foramen was situated within 7 mm of the posterior edge of the mandible in only 3.3% of cases.

Tsai (2004) studied three hundred and eleven Taiwanese children to evaluate the position of the mandibular foramen from deciduous to early permanent dentition using panoramic radiographs. Through all stages, the results revealed that the distances between the mandibular foramen and anterior border of the ramus were larger than those between the mandibular foramen and posterior border of the ramus. However, there was little change through all stages with regard to the distance from the mandibular foramen to the alveolar crest. There were a negative correlation between the gonial angle and the distances from the mandibular foramen to each mandibular border. Evaluation of the mandibular foramen from the oral aspect can be influenced by the degree of mouth opening.

Movahhed *et al.* (2011) used two hundred panoramic radiographs and two hundred mandibular dental casts related to patients aged 7-10 years there being 106 girls and 94 boys who were divided to four age groups of 7, 8, 9 and 10 years. The distance between the most anterosuperior point of the mandibular foramen to the occlusal plane, to the anterior, posterior and inferior borders of ramus and gonial angle was measured. In about 4% of 7 years old, who were all girls, the most anterosuperior point of the mandibular foramen was above the occlusal plane. This percentage increased to 86% in both sexes in children aged 10 years. There were significant differences between the most anterosuperior point of the mandibular foramen and occlusal plane with both age and sex. However, there were no significant differences between sides. There was a negative correlation between the mandibular angle and the distances between the most anterosuperior points of the mandibular foramen to each mandibular border. This study concluded by saying the inferior alveolar nerve anaesthesia should be administered above the occlusal plane in 10 year-old children.

2.4.3 Papers Related to Studies Using Cadavers

Narayana & Vasudha (2004) evaluated the position of the mandibular foramen in twelve right and fourteen left cadaveric hemi-mandibles. The distances from the mandibular foramen to the angle, symphysis menti, 3rd molar, and the lowest point of the mandibular notch were measured. There were no significant differences between right and left sides with regard to the distances from the mandibular foramen to different landmarks except the distance to the symphysis menti. Overall, the mandibular foramen was positioned at a symmetrical point on the ramus on either side. The study concluded that the position of the mandibular foramen varies from bone to bone despite its bilateral symmetry.

2.4.4 Papers Related to Studies Using Scanning Methods

Peker *et al*.(2009) examined six edentulous human mandibles of unknown age and sex to evaluate the efficiency of conventional and digital panoramic images for localization of mandibular foramen. A measurement error between the radiographic and direct measurements was determined at the level of 1 mm. The measurement errors in conventional panoramic radiography were less than digital panoramic images. There were strong positive statistical correlations between direct and radiographic measurements based on Pearson correlation coefficient. There were significant differences between radiographic and direct measurements with regard to the distances from the superior point of the mandibular foramen to mandibular notch and to the inferior border of the of the ramus. Accordingly, it was concluded that the diagnostic performance of conventional and digital panoramic images are equal for the localization of mandibular foramen. In the mandible, there was a correlation between vertical radiographic measurements and direct measurements for conventional and digital panoramic radiography.

Poonacha *et al*.(2010) studied one hundred and eighty children of dental age range from 3 to 13 years, to assess the relative position of the mandibular foramen. The sample was divided into 6 age groups each of thirty children, based on the Hellman's dental developmental stages. The gonial angle and its relationship with distances between different mandibular borders in growing children were measured. The position of the mandibular foramen was assessed and compared in different age groups to determine the growth pattern of the mandible and changes in the location of the mandibular foramen. The results revealed that the distance from the mandibular foramen to the anterior plane of the ramus were greater than that from the mandibular foramen to the posterior plane of the ramus through all stages. In the late mixed dentition period, there was a maximum increase in the vertical dimensions of the mandible compared with the horizontal dimensions. The study concluded that the position of the mandibular foramen did not change in relationship to the mandible and its growth.

Angel *et al.*(2011) evaluated one hundred and sixty five dentate adult patients there being one hundred and ten females and fifty five males, aged from 18 to 80 years. The influence of age and sex on the relative position of inferior alveolar canal and its foramina was determined using cone-beam computed tomography. The position of the mandibular foramen was assessed in axial view, while, the inferior alveolar canal in coronal view. The position of the mandibular foramen from the anterior to the posterior border of the ramus and for the inferior alveolar canal at the level of first permanent molar from the nearest buccal bony surface to the lingual surface and from the superior alveolar crest to the inferior border were measured. This study revealed the relative location of the inferior alveolar canal and the mandibular foramen in adults in related to age and sex remain fairly constant.

[****]Comment: Many of the descriptions give in the original texts as to the geographical origin, ethnic group and the method of collection and recoding of samples were lacking in detail, as were methods of preparing skulls (e.g. hemi-sectioning). The words, as given in the original papers, were used in the above abstracts so as to avoid speculation.

Chapter 3
Bone Growth

3.1 Factors Effecting Bone Growth

Gene expression results in the regulation of downstream pathways and interactions with other genes that are essential for bone development. However, the actual mechanisms are not fully understood. The following paragraphs indicate some of the more important genes involved in the facial bones development as outlined in the literature.

3.1.1 Local Factors

Local factors influence bone development and growth, such as physical activity (muscles), missing teeth, oral habits and local diseases. Physical exercise helps muscles grow and get stronger, and consequently, bone changes its physical shape to tolerate new stresses. Similarly, atrophied muscles result in weakened bones (Ruff, 2006). Atrophy in masticatory muscles change the craniofacial morphology (Tsai *et al.*, 2010). In patients with congenital missing teeth, many craniofacial morphological changes have been noted such as short maxillary and mandibular lengths, decreased anterior facial height and mandibular prognathism (Lisson & Scholtes, 2005). Habits such as bruxism (habitual, involuntary grinding or clenching of the teeth) and finger sucking can change oral function and accordingly, orofacial morphology is influenced significantly (Josell, 1995). Local diseases such as bone malignancy, Bell's palsy and periapical abscess may result in bone remodelling (Curtis *et al.*, 1986; Cohen Jr, 1995; Rossi *et al.*, 2003).

3.1.2 Systemic Factors

A number of systemic factors affect bone growth and development, including, nutrition, hormone secretion and sunlight exposure time. Dietary intakes are very important for healthy bone growth specially in adolescent life stage (Whiting *et al.*, 2004). Chronic alcohol abuse can reduce bone volume, trabecular number, mineral content and thickness. (Trevisiol *et al.*, 2007). Cranial bone shape changes during the growth period as a result of metabolic disorders related to hypocalcaemia and secondary hyperparathyroidism (Engström *et al.*, 1988).

Modelling and remodelling of bone are physiological regulatory processes in which the bone is resorbed and formed through the differentiation and proliferation of the osteoblasts and osteoclasts cells (Krane, 2005). These processes are influenced negatively with boron deficient diet, choline deficiency, oxygen and age. They are also regulated by some genes such as Cas interacting Zinc finger protein (Ciz), Bmp2, Cox2, Cbfa1, Akt1 and RANKL (Chikazu *et al.*, 2002; Gorustovich *et al.*, 2003; Gorustovich *et al.*, 2006; Kawamura *et al.*, 2007; Gorustovich *et al.*, 2008; Lee *et al.*, 2012) . In human adults, about ten per cent of bone mass is replaced every year, which means the whole bone structure needs a decade to complete the remodelling process.(Alliston & Derynck, 2002)

In the absence of local or systemic diseases which affect bone morphology, it can be concluded that facial bone morphological modifications are, in all probability, due to genetic influences in particular, with perhaps some influence by musculature.

3.1.3 Genetic Factors

Facial bones form indirectly through differentiation of cranial neural crest cells (CNCC). Most facial bones including the mandible, maxilla, (including alveolar bone), frontal, zygomatic, nasal, vomer, lacrimal and palatal bones develop by intramembranous ossification, whereas, the ethmoid and sphenoid bones form by endochondral ossification (Osumi-Yamashita *et al.*, 1997; Lee *et al.*, 2001).

Cranial neural crest cells migrate ventrally from the neural tube to form the first branchial arch which subsequently subdivides to form the maxillary process and mandibular process in which the maxilla and mandible respectively develop (Balic *et al.*, 2009). The migration of the CNCC into the first branchial arch is regulated by multiple factors including the site of ethnic group in the neural tube, the location at which the CNCC reside in the arch after the migration, closeness to signalling centres in both surface ectoderm and the pharyngeal endoderm, and the genetic composition within the cells of the CNCC. These factors together are responsible for the spatial information that is essential for formation of the final skeletal pattern (Knight & Schilling, 2006).

Several genes mediate the migration of neural crest cells. The expression of cadherin-catenin complexes in particular c-cad 7, α-catenin and β-catenin are required for the initiation and completion of CNCC migration (Nakagawa & Takeichi, 1995, 1998; de Melker *et al.*, 2004). In addition, ITGα1 promotes the migration of crest cells probably through binding with the extracellular matrix (ECM) which is known to be involved in cell movement (Lallier & Bronner-Fraser, 1993; Kil *et al.*, 1996). Thereafter, other genes are crucially important for the proper development and formation of the facial bones.

Paired related homeobox genes (Prx1 & Prx2), are transcription factors which play a pivotal function in maxillofacial development. In Prx1 and Prx2 double mutant mice, the maxilla and mandible were malformed, shortened and fused at the midline, with loss of mandibular incisors. It seems Prx gene products are required for the expression of diverse regulatory genes in the lateral and medial regions of the mandibular process, including genes regulating tooth development (Pax9 & Fgf8). Also in these mutant animals, the level of sonic hedgehog (Shh) was significant reduced, indicative of a role for Prx genes in indirect regulation of Shh. The pharmaceutical inhibition of Shh signalling contributes at least in part to the defects in the formation of the mandible and incisors in Prx mutants (ten Berge *et al.*, 2001; Balic *et al.*, 2009). Prx1 and Prx2 have a direct or indirect role in the regulation of the downstream genes, eHand, Msx1 and Bmp4 in the medial mandibular mesenchyme. Whereas, Msx2 is shown to be directly inhibited by the transcription repressors Prx1 and Prx2 (Liu *et al.*, 2005). In addition to the extension of Fgf8 and its target genes (Barx1, Dlx5 & Oitx1) from the lateral into the medial region (Balic *et al.*, 2009). Sox9 is the marker for the chondrogenic condensation process, and in the Prx1/Prx2 double mutant referred to above was absent in the main body of the Meckel's cartilage, consequently, the major part of the cartilage was lost (Balic *et al.*, 2009).

Msx is transcription regulator protein for a range of target genes through interaction with gene promoters and components of the transcription complex. Msx1 and Msx2 play a pivotal function in the development of the mandible, maxilla and frontal bone and double mutant mice show an absence of bone matrix in the frontal bone and severely deformed jaws (Han *et al.*, 2007).

A reduction in the levels of Msx1 and Msx2 regulated other genes in the double mutant mice: Runt-related gene 2 (Runx2) which is a transcription factor considered a significant marker of osteoblast differentiation and osteogenesis in neural crest and mesoderm derived bones; Osteocalcin (Osterix), a differentiation marker of osteoblast has been shown to be regulated through direct interactions with Msx1 and Dlx1; Dlx5, another important marker for osteoblast differentiation. Although Dlx5 was undetected in the frontal primordium, expression of Dlx5 is known to be regulated by Msx1 and Msx2 (Han *et al.*, 2007); In Msx1 and Dlx5 mutant mice, the frontal bone defect was verified, as well as defect of mandible and sphenoid. Msx1 and Dlx5 interactions have an important role in regulating osteogenesis during frontal bone morphogenesis (Chung *et al.*, 2010). However, in the palate, Msx1 does not appear to regulate expression levels of Dlx5 (Levi *et al.*, 2006; Han *et al.*, 2009).

It was noted in the Msx1 double mutant mice, that development of teeth and the alveolar bone was inhibited because expression of Msx1 was blocked. Therefore, the Msx1 gene appears to regulate teeth and the alveolar bone formation through the expression of its downstream target gene Bmp4. Application of Bmp4 in these mice rescues the alveolar bone development and the expression of its downstream genes Cbfa1 and Dlx5 in the dental mesenchyme (Zhang *et al.*, 2003).

Distal-less homeobox (Dlx) is a transcription factor gene family important for facial skeletal structures development. In the first branchial arch, the maxillary and the mandibular processes express Dlx1 and Dlx2, whereas Dlx3, Dlx5 & Dlx6 are expressed only in the mandibular process, in a lateral medial gradient. Dlx1 and Dlx2 mutants can show loss of all maxillary molar teeth (Qiu *et al.*, 1997; Thomas *et al.*, 2000). In Dlx5 mutant mice, the mandible is shortened, with loss of its coronoid process and the condylar process and angular process are misshapen (Acampora *et al.*, 1999). Also in Dlx5 double mutant mice there is incomplete palatal bone fusion

(Levi *et al.*, 2006). Also the height of the rugae is increased with 40% and a groove in hard palate was detected (Han *et al.*, 2009). In humans, a translocation breakpoint has been reported in a patient with split hand/split foot disease (SHSF) at 7q21.3 which seems associated with the disruption of genes including Dlx5 and Dlx6. These patients develop a bone malformation including cleft palate and mandibular prognathism (Ignatius *et al.*, 1996). Consistent with the these results, Depew et al, (2002) showed that null mutations in Dlx5 and Dlx6 result in a homeotic transformation of the lower jaw into an upper jaw.

In detailed Dlx5 mutant studies, it was found there is a remarkable decrease in Fgf7 while there is an increase in the expansion of sonic hedgehog (Shh) expression in the nasopalatal mesenchyme. Dlx5 which is expressed in the nasopalatal mesenchyme is needed to inhibit Shh expression through the regulation of Fgf7 signalling. The cascades of Shh signalling is important to promote cell proliferation of palatal mesenchyme and also rescues palatal fusion (Han *et al.*, 2009). Also it is reported that Fgf8 promotes Dlx5 expression in mandibular primordium and Dlx2 expression in the mandibular and maxillary primordia (Ferguson *et al.*, 2000). However, a restricted area in the anterior palate is considered a signalling centre in which many genes are expressed including Msx1, Shh, Bmp, and Wnt required for palatal growth (Levi *et al.*, 2006).

Barlow & Francis-West, stated (1997) that the high expression of Bmp2 and Bmp4 activate the expression of Msx1 and Msx2 during the development of facial primordia. This activation is correlated with the expression of Shh and bifurcation of the palatine bone in the maxillary primordium and with Fgf-4 expression and bifurcation of Meckel's cartilage in the mandibular primordium. They also showed that Bmp2 and Bmp4 are part of a signalling cascade that controls proliferation, outgrowth and patterning of the facial primordia. Bmp2 and Bmp4 indirectly regulate the expression of Fgf4 in the mandibular primordium and Shh in the maxillary primordium through Msx1 and Msx2 expression.

Bone Morphogenic Proteins (BMPs) are growth factors that are considered as a member of transforming growth factor β (TGFβ) superfamily. Bmp signalling proteins have an important function in osteoblast differentiation and postnatal bone development. Smad molecules 1, 5 and 8 are the downstream proteins of Bmp receptors and perform a crucial role in Bmp signalling cascades (Cao & Chen, 2005). The heterodimers of Smads 1 and 5 interact with Runx2 in order to promote the transcription of target genes such as COX-2 and type X collagen (Col-X) in osteoblasts and also stimulate osteoblast differentiation (Leboy *et al.*, 2001; Chikazu *et al.*, 2002). Smad1 also interacts with the DNA sequence of Hoxc8 gene to activate the transcription of osteopontin, which is a marker protein for osteoblast maturation (Yang *et al.*, 2000). In addition to Smad signalling, Bmps can activate non-Smad signalling pathways such as JNK and p38 signalling pathways to induce osteoblastic cell differentiation (Guicheux *et al.*, 2003).

Reports from transgenic and knockout mice and humans with naturally occurring mutations in Bmps and their receptors have revealed the functional significance of Bmps in the development and formation of bone and cartilage. Mutations in Bmp, Bmp receptors and Smad genes cause a number of severe defects in bone development (Cao & Chen, 2005; Plouhinec *et al.*, 2011).

Chapter 4
Anatomical Considerations

4.1 Relations of Nerves to Facial Foramina

4.1.1 Trigeminal Nerve

The trigeminal nerve is the fifth and largest of the cranial nerves. It has motor fibres which supply the muscles of mastication plus anterior belly of mylohyoid and sensory fibres which supply the skin of the scalp, face, mouth, teeth, nasal cavity and paranasal sinuses. The trigeminal nerve emerges from the anterior surface of the pons then passes forward out of the posterior cranial fossa (Snell, 1986). The cell bodies of its sensory fibres originate from the trigeminal ganglion to innervate the ipsilateral side of the face. This ganglion lies partly in Meckel's cave in the floor of the middle cranial fossa. The motor fibres pass laterally and inferiorly under the trigeminal ganglion. These fibres leave the middle cranial fossa along with the mandibular division via the foramen ovale, then unite together to form a single nerve trunk (Malamed, 1997). The trigeminal nerve branches into three large trunks, the ophthalmic division, the maxillary division and the mandibular division.

4.1.1.1 Ophthalmic Division

This division is the first and the smallest branch of the trigeminal nerve and is purely sensory. It passes anteriorly in the lateral wall of the cavernous sinus below the oculomotor and trochlear cranial nerves. It enters the orbital cavity via the superior orbital fissure. The length of this division is approximately 2.5 cm. It divides into three branches (lacrimal nerve, the frontal nerve and the nasociliary nerve) just before it passes through the superior orbital fissure.

The frontal nerve is the largest branch of the ophthalmic division. It passes anteriorly in the roof of the orbit to divide into the supratrochlear and the supraorbital nerves (Malamed, 1997). The supratrochlear nerve winds around the superior orbital margin medial to supraorbital nerve. It supplies the conjunctiva, the skin of the medial surface of the forehead, medial surface of the upper eyelid, the scalp and the lambdoidal suture. It travels backwards close to the median plane to reach the vertex of the skull (Snell, 1986; Malamed, 1997).

The supraorbital nerve turns around the superior orbital margin at the supraorbital notch. It gives off two branches, lateral and medial branches, which supply the skin and conjunctiva of the central part of the upper eyelid, and the skin of the forehead (Snell, 1986).

4.1.1.2 Maxillary Division

The maxillary division is the second division of the trigeminal nerve. It is intermediate in size between the ophthalmic and the mandibular nerves. This nerve is exclusively sensory. When the maxillary division enters the infraorbital groove and canal it is known as the infraorbital nerve and eventually emerges on to the face via infraorbital foramen. The infraorbital nerve is the terminal branch of the maxillary division, It then divides into three terminal branches, palpebral, nasal, and labial to innervate the skin of lower eyelid, the skin of the lateral surface of the nose and the skin and mucous membranes of the of the upper lip respectively. The labial branch was the largest branch of the infraorbital nerve provides the most sub-branches (Roberts & Sowray., 1987; Malamed, 1997; Hu *et al.*, 2006).

The infraorbital nerve enters the inferior orbital canal where (at its posterior part) it gives two very important branches particularly for a dentist, the middle superior and anterior superior alveolar nerves. The middle superior alveolar nerve supplies the upper premolars and sometimes the mesiobuccal root of the first maxillary molar and their surrounding tissues. The anterior superior alveolar nerve passes downward through the anterior wall of the maxillary sinus to supply the anterior teeth and their surrounding tissues (Roberts & Sowray., 1987; Malamed, 1997).

4.1.1.3 Mandibular Division

The mandibular division is the third and largest branch of the trigeminal cranial nerve. This nerve is a mixed nerve, which contains all the fibres from the motor nucleus of the trigeminal nerve. The mandibular division divides into two trunks, an anterior division and a posterior division.

The lingual nerve is the second branch of the posterior division. It runs downward medial to the lateral pterygoid muscle then continues between medial pterygoid and ramus. After that, it passes forward medial to the inferior alveolar nerve beneath the lower border of the superior constrictor muscle of the pharynx, to reach the lingual surface of the lower third molar. It then turns below and medial to the submandibular duct (Warton's duct), at this point, it gives off terminal branches. The lingual nerve gives off small branches to innervate the lingual gingivae of the lower jaw and sublingual nerve to supply the mucous membrane of the floor of the mouth. The terminal branches of the lingual nerve provide general sensation and taste sensation to the anterior two thirds of the tongue (Malamed, 1997; Snell, 2000).

The inferior alveolar nerve is the largest branch of the mandibular division of the trigeminal nerve. It runs, lateral to the lingual nerve and medial to the lateral pterygoid muscle, it continues, downward and medial to the ramus to reach the mandibular foramen from which it enters to pass through the mandibular canal with inferior alveolar vessels. Just before it enters the foramen, it gives off the mylohyoid nerve which provides motor fibres to the mylohyoid muscle and anterior belly of digastric muscle. In the mandibular canal, it gives off several small branches which provide sensory fibres to teeth and its gingivae of the mandible. Finally the inferior alveolar nerve divides to give off its terminal branches, the incisive nerve to supply the anterior teeth and the mental nerve which emerges via the mental foramen, to supply the buccal gingivae of between the midline and the lower second premolar, the skin of the chin, the skin and the mucous membrane of the lower lip (Malamed, 1997; Snell, 2000).

Chapter 5
Aims and Objectives

5.1 Overall Aim

- The aim of the study is to determine the landmarks that would provide the most reliable and predictable indicators of the position of the supraorbital, infraorbital, mental and mandibular foramina in human skulls of Hokien, Hylam, Indian and British populations (for geographic origin see page 101) of ranging ages using an electronic digital calliper device and an 3D laser scanning, which would provide clinicians with suitable modifications in technique to accommodate these variations.

5.2 Aims

- To evaluate the presence or absence of symmetry of the positions of four maxillofacial foramina in relation to specific anatomical landmarks in human skulls from each of the four populations.
- To determine differences between ipsilateral measurements from defined points on each foramen to defined points on stated anatomical landmarks, in the four population groups.
- To evaluate the presence or absence of symmetry of the positions of four maxillofacial foramina in four defined age groups in each of the four population groups.
- To determine the relationship between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible, on both sides of the skulls of each population group.
- To determine the differences between ipsilateral measurements from each foramen to stated anatomical landmarks using electronic digital calliper and 3D laser scanning measurements in the four population groups.

5.3 Objectives

- To compare the position of each of four maxillofacial foramina in the four population groups
- To make intra-population comparisons between right and left sides in each population groups.
- To make inter-population comparisons between ipsilateral measurements from defined points on each foramen to defined points on stated anatomical landmarks in each population group.
- To make intra-population comparisons with respect to age in each of the four population groups.
- To observe if there are any correlations between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible, on both sides of the skulls of each population group.

5.4 Null Hypotheses

- In each of the four population groups, there are no significant differences between right and left measurements between each foramen and stated anatomical landmarks.
- There are no significant differences between ipsilateral measurements from each foramen to stated anatomical landmarks in the four population groups.
- There are no significant differences between ipsilateral measurements from each foramen to stated anatomical landmarks in each of four age groups in the four population groups.
- There are no correlations between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible, on both sides of the skulls of each population group.
- There are no significant differences between ipsilateral measurement from each foramen to stated anatomical landmarks in the four population groups using electronic digital calliper and 3D laser scanning measurement.

Chapter 6
Preliminary Study
Age Assessment by Tooth Wear Pattern

6.1 The Importance of Age Assessment

In the main study, skulls from four populations are used to study the relative positions of four cranial foramina. Two populations are unique in that the age of each skull was registered at death. Thus both the age range and the distribution of ages within this range are known. This cannot be said of the other two populations.

There are two principal reasons why the age of all skulls should be known.

1. The position of the cranial foramina relative to fixed anatomical points may be age related, though it is acknowledged that bone growth is not a major factor after the closure of sutures at approximately the time of third molar eruption. It has also been cited (Wilkinson, 2004) that the soft parts of the face vary more than the bone elements of the skulls between population groups. However, to make a definite statement regarding age related growth, or lack of it, after 17 years of age, it was decided to age the two groups of unknown age, prior to data collection of foraminal positions.
2. To arrive at a meaningful comparison of the populations, they should have similar age ranges and distribution of ages.

Skull growth occurs at the margins of membrane bones, in which the growth of the skull vault takes place; the growth regions between the bones of the skull base are cartilaginous and are referred to as synchronous. Normally, the size of the calvaria increases until 16 years old, and then during the following 3-4 years the size is slightly increased as a result of thickening of its bones. At the same period, the bones of the face and jaws are rapidly growing (Moore, 2003).

Though all skulls in the study were, according to the eruption of the third molar, at least 18 years or so old, it was considered desirable to be able to discuss data with regards to age within populations, if only to show that, in an adult, age differences did not affect foramina relationships.

Therefore, a series of preliminary studies were undertaken in order to age the skulls in the two 'un-aged' populations.

6.2 Literature Review

6.2.1 Age Assessment in Children

This section reviews the papers relating to age assessment by tooth eruption. This is important as most, if not all, of the schemes which assess age by tooth wear, first compile a group of young children and adults of 'known age' assessed from eruption patterns.

Before the work of Logan & Kronfeld (1933) it was held that calcification of all permanent teeth began at the same time. It is now generally agreed that the development of the dentition commences at differing stages in childhood growth, dependent on the teeth in question, and that variation in eruption times varies according to inherent biological variability. A succession of stages occurs that is common to all humans and all teeth, both deciduous and permanent. These stages are predictable and observable and it is the observation of these stages on which many age assessment methods are based. The data of Logan & Kronfeld (1933) was derived from 25 fresh post-mortem specimens of which 19 were under 2 years of age.

Schour & Massler (1941) used these data and compiled two charts showing schematically, the development of the human dentition. The information in charts has been extensively used over the years and has proved to be relatively accurate in spite of the small sample size on which they are based. In their paper there is no mention of sample size nor are any references given. Because eruption is much more amenable to visual assessment than actual tooth formation, it has been most often relied upon for age determination. While the charts also depict the stages of the formation of each tooth in relation to the others, it is the eruption sequence that is most commonly used for age estimation.

Hunt & Gleiser (1955) concluded that the age of preadolescent children (from American White children from Boston, Massachusetts) can be assessed from the sequence of calcification and eruption of the permanent mandibular first molar using radiographs of a child's jaws at any age. The results found that dental maturation in both sexes is slightly different.

Arvystas (1974) studied the eruption patterns of a family of three children and the relationship between the eruption times and chronological age was investigated. This small sample size makes any conclusions to be of doubtful value.

Biggerstaff (1977) agreed with the problem of small sample size and that this should be taken into consideration when considering conclusions reached in such studies. Moreover, the differences between population groups should be considered.

However the work of Edler (1977) who studied the dental ages of fourteen patients who were receiving hormone therapy, confirmed that dental development is less sensitive to factors such as nutritional and endocrine factors than skeletal development. His study revealed that delay in dental age is very much less than in skeletal age. He concluded that the eruption patterns of teeth of children can be confidently used to estimate the chronological age even in cases of growth hormone deficiency.

In a large sample of three thousand seven hundred and forty four of Iranian population, Moslemi (2004) investigated the time and sequence of eruption of permanent teeth. The sequence of eruption of the teeth in girls and in boys was given in his study.

Boccone *et al.*(2010) reported on an Egyptian population "Giovanni Marro", where the age of one hundred and thirty subjects was assessed from tooth eruption and mineralization, as well as the anthropometric variables of the limb bones and the ilium. This study showed that tooth eruption and dental mineralization gave a more accurate age assessment than skeletal measurements.

Soliman *et al.*(2011) reported on a cross-sectional sample of one thousand one hundred and twelve to determine the dates of emergence of deciduous teeth in Egyptian infants aged from 4 to 36 months. Eruption sequence followed a typical pattern. The average time of emergence of the deciduous teeth was 17.8 and 15.8 months in the mandible and maxilla respectively for boys, and 22.1 and 20.1 months respectively for girls. The data was compared with those from other studies. Egyptian children were similar to Saudi Arabians and Nigerians, but were earlier than Iraqis and Nepalese, and later than white Americans. The authors concluded that current findings could best be used for assessing dental growth and development in Egyptian populations.

Blenkin & Taylor (2012) analyzed previously collected Australian material. They developed charts which they claimed were reliable tools for estimating age at death of aboriginal Australian populations.

More precise and detailed techniques of age estimation have been published (Gustafson, 1950; Gleiser & Hunt, 1955; Demirjian *et al.*, 1973). However these methods require tooth extraction and preparation of microscopic sections of teeth, are time-consuming and cost-inefficient. In addition, this invasive approach may not be practical for ethical, religious, cultural or scientific reasons. Furthermore, other techniques such as those of Moorrees *et al.*(1963), Demirjian *et al.*(1973) and Anderson *et al.*(1976) require radiographic observation which need time and ethical approval. Although Solheim & Sundnes (1980) found the Miles (1962) method for age assessment to be slightly less reliable than those methods, the fact that removal of individual teeth and their destruction for the purpose of microscopic examination is not called for. It is however out with the scope of the present study to review these more precise methods.

Conclusion

It is interesting to note that despite the small sample used by Schour & Massler (1941) compared to the large sample of Blenkin & Taylor (2012) the atlas style charts produced by both these authors, and others, are very similar.

The consensus of opinion is that dental maturation is sex specific. Generally, in girls the average age at eruption of permanent teeth is earlier than in boys (Hunt & Gleiser, 1955; Moslemi, 2004).

The eruption patterns in children are relatively unaffected by growth hormone difficiency (Edler, 1977).

The degree of tooth eruption and dental mineralization for age assessment was more accurate than that assessed from measurements of the long bones of the limbs or ilium (Boccone *et al.*, 2010).

It is therefore concluded that estimation of ages of young individuals can be obtained with relative accuracy, based on the order of tooth eruption from infancy to about 21 years. The age assessment of individuals of 28 years and older is more challenging (Brooks, 1955).

6.2.2 Age Assessment in Adults

Tooth wear is defined as the loss of tooth substance by contact of tooth on tooth during mastication, accelerated by predisposing factors such as the abrasive effect of the hard materials which may be present in the food (Campbell, 1939).

Miles (1962) defined attrition as a continuous loss process of the occlusal and incisal surfaces of teeth and postulated it as being regular in rate in any one population group.

Reeder (1953) demonstrated that tooth wear patterns are not solely a function of age, being significantly influenced by specific types of food. Softer food would be expected to result in less tooth tissue loss than harder food in a given time, in any given population.

Weiner *et al.* (1953) stated that wear scores are useful when dealing with archaeological material, not only in assessing age, but also in helping to define the age distribution of individuals within a population.

Hojo (1954) reported that tooth wear patterns may be useful in assessment of age at death. He produced a tooth attrition/age diagram which showed only slight changes in relation to age.

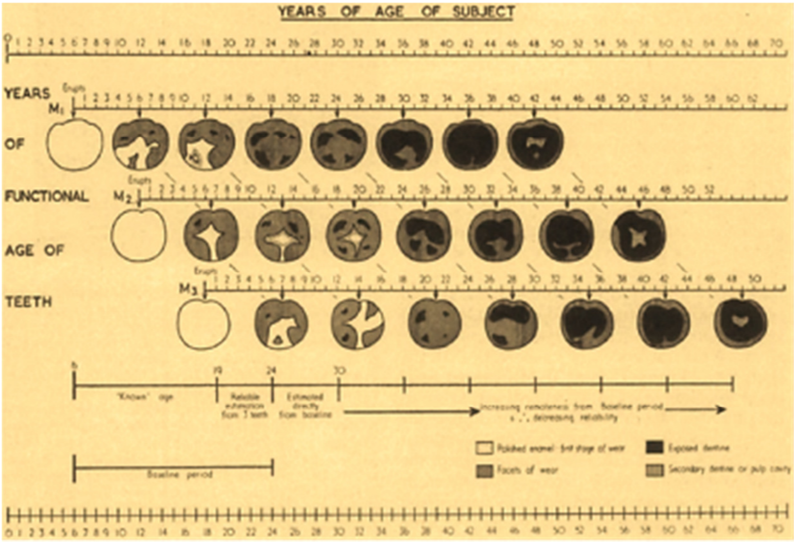
Miles (1958) stated that the accuracy of age assessment from the dentition varies with age. Up to age 14 years, the results produced an error of little more than one year. Up to 20 years, age assessment by wear gave a moderately high result. He concluded also that there was no significant correlation between age and tooth wear pattern over the age of 50 years.

Murphy (1959) produced an age assessment chart based on tooth wear patterns. Dentine becomes exposed at the centre of an attrition facet forming an area of wear surrounded by enamel. The dentinal area is characteristically saucer-shaped with a peripheral border or base. He postulated that there were eight distinct stages of wear related to age.

Miles (1962) used Anglo-Saxon skulls obtained from an archaeological excavation at Breedon, Leicestershire, England. Half of the skulls had reasonably complete dentitions, thirty two being juveniles with immature dentitions. This group of thirty two skulls was regarded as a group of subjects of known ages ranging from 6 years to 18 or 19 years as assessed by tooth eruption, and constituted a "known age" group. The functional life of the first molar (M1) from the time of eruption at about 6 years, to the end of its first twelve years in function, was nicely displayed in this group. It was found that at 18 years of age the second molar (M2) after 6 years in function, showed slightly less wear than M1, after the same number of years in function.

In this way the data from the 'known age' group were projected forward for another six years to extend the period of what could be regarded as reasonably confident estimation, up to the age of 24 years. This new group, aged up to 24 years, when added to the thirty two skulls of 'younger known age' group provided thirty eight skulls ranging from 6 years up to 24 years providing a basis on which M1 wear, up to 18 years, could be compared to 12 years of M2 wear and up to 6 years of third molar (M3) wear. These thirty eight skulls were regarded as the baseline group on which the ages of the other specimens could be assessed. Using this method he produced an age assessment chart based on tooth wear patterns (Figure 1).

Figure 1: Age assessment according to occlusal attrition patterns (Miles, 1962)



Lavelle (1970) studied and compared attrition in three hundred fifty nine maxillary and mandibular molar dentitions from Anglo-Saxon, Mongoloid, West African, Australian aborigine and 19th century British skulls using the assessment criteria of Murphy (1959). The latter population showed a relative lack of attrition compared to the former four. This feature was confirmed on examination of three hundred maxillary and mandibular molar dentitions from present-day British material. Initially, the degree of molar attrition was categorized according to the amount of exposed dentin. Then each molar tooth was compared with adjoining and corresponding molars, within the same or different population samples. It was suggested that the variation in molar attrition reflected the different dietary consistencies of the population samples. This study showed that there was no significant difference in attrition between the maxillary and mandibular molars of the same population sample, in comparison to the difference between population samples. There was also no significant difference between molar wear patterns of males and females in the modern British dentitions, although there was no information regarding the other populations. There was considerable variation in the grades of attrition between the molars, either within or between the population samples. These comparisons were only approximate. The study concluded that the main cause of tooth attrition is age.

Molnar (1971) studied tooth wear patterns among skeletal remains of North American Indians from three areas, California, the Southwest and the Valley of Mexico. This study revealed significant differences in type and degree of tooth wear pattern between the three populations, and between sexes in one population. In the Californian population there was a difference in degree of tooth wear patterns between males and females. The direction and the form of the occlusal surface were recorded to describe the type of the tooth wear patterns. This study concluded that there was a significant difference in tooth wear patterns between Californian and the Southwest or Californian and Mexico populations. However, there were similar patterns in the Southwest and Mexico populations.

Johnson (1976) used two hundred and thirteen British skulls of known age at death there being 183 were aged 21-88 years and a further 30 skulls were aged to be less than 21 years. The ages were assessed by suture closure and tooth attrition and categorised as either less than 35 years or greater than 35 years at death. Attrition aging was a significantly better method than using lambdoidal, coronal or sagittal suture closure.

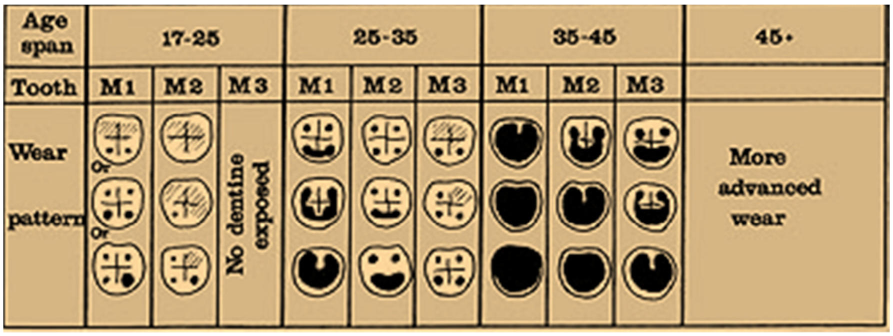
Nowell (1978) assessed the age of the Tepe Hissar (Iran) population, using "Miles" method. In this study, no consistent difference in the rate of tooth wear pattern between the first and second or first and third molars was noted. The authors stated their data validated the Miles' method of ageing.

Helm & Prydso (1979) using two hundred and thirty five Danish medieval skulls recorded the stages of occlusal attrition of the permanent mandibular molars. Compared with contemporary Danish children, the age at eruption of permanent teeth was similar and the rate of attrition of the first and second molars was similar. Third molar emergence was assessed at the early age of 14 years. They concluded that age assessment at death is more accurate in the age range 5–30 years, decreasing after 40 years of age.

Scott (1979) reported a dental attrition scoring technique for molar teeth involving a quadrant system which was applied to three Amerindian skeletal samples. Molar teeth were visually divided into four sections and each section scored on a 1–10 scale. This study showed that their method was reliable, easy to use and produced data with lower variances than Molnar's eight stage system.

Brothwell (1981) stated that tooth attrition is useful in age assessment. In his studies, the degrees of wear were checked against age, as assessed from the pubic symphyseal face. He warns that attrition standards established in one population should not be used to assess age in another population or era. He agreed with Miles (1962) that the rates of wear in earlier British populations did not appear to have changed much from Neolithic to Medieval times, and his attrition chart should be roughly correct for all these periods. From his work and based on Miles (1962), he produced an age assessment chart (Figure 2) allocating individuals to four age groups.

Figure 2: Age assessment according to occlusal wear patterns (Brothwell 1981)



Takei *et al.*(1981) assessed the rates of tooth wear patterns in full dentitions [28 teeth, less permanent molars] to produce an age assessment table. The results indicated that the correlation coefficient between the assessed ages when all 28 teeth were used, or when either one or the other of homonymous teeth were used, or when 14 maxillary teeth were compared with 14 mandibular teeth, were 0.929, 0.895, 0.889 and 0.868 respectively. It was concluded that any one of these methods was of sufficient value for practical purposes.

Kieser *et al.*(1983) used artificial stone casts of the dental arcades of two hundred and two living Lengua Indians from Paraguay, in an evaluation of the accuracy of the "Miles" method. Independent age estimates from maxillae and mandibles of the same individuals were found to be highly correlated with each other and to the actual ages of those individuals, supporting the validity of the "Miles" method.

Smith (1984) measured and analysed molar wear in five groups of hunter-gatherers and five groups of agriculturalists. Wear plane angles were evaluated in teeth which were at the same stage of occlusal surface wear using Murphy's eight stage system. A good relationship existed between tooth attrition patterns and the type of food. Hunter-gatherers, whose food was rough, showed worn, almost flat, molar surfaces. In populations, whose food was based on wheat or corn, wear patterns changed and the worn molar surfaces tended to be more oblique. The latter developed higher angles than did hunter-gatherers, ultimately reaching a 10° difference. This suggests that caution must be exercised when using tooth wear patterns as an age assessment criterion.

Lovejoy (1985) studied a sample of three hundred and thirty two adult dentitions from the Libben American Indian population. The tooth wear patterns of these dentitions were described as similar to that provided by Murphy (1959a). Following this adult study the rate of wear of dentitions of children of age 6 to 18 years was determined by means of the Miles method (1958, 1962, 1963a, b, 1978), Brothwell (1963) and Johnson (1976). Maxillae and mandibles were aged and described independently and were not reassessed as complete individuals until after an age had been assigned to each. All individuals with significant premortem loss were then added to the sample. Using the assumption that wear accelerated with increasing tooth loss, the population was rearranged in age sequence. This study found that tooth wear pattern was an effective indicator of age even in a highly mixed anatomical population.

Brothwell (1989) reported on patterns of occlusal wear of molars in a study of three hundred and twenty eight early British individuals of Bronze Age to the Saxon period. He classified them in nine grades similar to Murphy (1959). There were no significant differences noted between males and females. The results revealed there were high correlations between wear scores and ages and he considered the patterns of dentine exposure to be a valuable age indicator in earlier populations.

Santini *et al.*(1990) evaluated the accuracy of simple ordinal scoring in recording tooth wear patterns and ageing skulls. In this study, sixty Chinese skulls of known age at death were investigated. Based on the scales of Miles and Brothwell, molar teeth of these skulls were scored for wear patterns using a 0 to 5 point scale. It was concluded that a simple ordinal scoring method ascribing one score per molar occlusal surface does not give a precise estimate of age at death.

Johansson *et al.*(1993) reported that a group of twenty individuals from a clinical standpoint aged from 16 to 56 years was examined twice in a period of 18 months to introduce a system for the longitudinal evaluation of the severity and the rate of progression of tooth wear pattern using study casts. Results indicated that occlusal wear scores in the incisor and canine regions were higher than in the posterior region. It was found that the overall progression, in an 18-month follow-up period, was slow. It was concluded that these scales may be utilized for determining the severity of occlusal wear.

Bell *et al.*(1998) conducted a study, using Australian aboriginal material, to quantify any differences in the form of dentinal scooping due to abrasion and erosion and by comparing the ratio of depth to breadth for the two modes of tooth wear pattern, to evaluate whether any alterations occurred in this ratio, with increasing age. They concluded that depth to breadth ratio of abrasion lesions does not seem to alter over time but required further investigation.

Kim *et al.*(2000) tested the accuracy of a new scoring system, in recording tooth wear patterns for age estimation, using dental casts of three hundred and eighty three individuals of known age all of whom had sound premolars and molars and a normal occlusion. The degree of tooth wear showed a significant positive correlation with age in both males and females. Tooth wear scores of males were higher than those of females. The authors reported they were able to estimate of an individual's age within ± 3 years in 42.4% of males and 49.4% of females, within ± 5 years in 61.8% of males and 63.3% of females. They found that they could very accurately place subjects into two age groups. The system is summarised below (Table 1).

Table 1: Scoring System of Tooth Wear (Kim et al, 2000)

Score	Premolar	Molar
0	No visible wear	
1	1P/1L	1P/1L/2P/2L
2	1P/2L/1S/1B	3P/3L/4P/4L/1S/1B/2S/2B
3	2S/2B	3S/3B/4S/4B
4	Wear on more than 2/3 occlusal surface	
5	1Pc/1Lc	1Pc/1Lc/2Pc/2Lc
6	2Pc/2Lc/1Sc/1Bc	3Pc/3Lc/4Pc/4Lc/1Sc/1Bc/2Sc/2Bc
7	2Sc/2Bc	3Sc/3Bc/4Sc/4Bc
8	Concavity on more than 2/3 occlusal wear	

P = Point-like wear facet less than approximately I mm in diameter.

L = Linear wear facet less than approximately 1 mm in width.

S = Surface-like wear facet more than approximately 1 mm in diameter.

B = Band-like wear facet more than approximately 1 mm in width or wear facet involving more than two surfaces.

Notes: “/” means 'or'.

“c”(concavity) means the wear of dentin.

Millard & Gowland (2002) used material obtained from ten Roman and Anglo-Saxon cemeteries. Statistical probability methods were used to assess age by wear. Moreover, they claimed that their version of the Miles’ method reduced some uncertainty in age determination. Generally their method produced older ages than traditional methods, especially in individuals showing heavy degrees of tooth wear patterns.

6.3 Age Assessment of Skulls Used in the Main Study

The following sections outline a series of preliminary studies undertaken to arrive at an appropriate age assessment method to be used in the main study.

In the following sections the words 'precision' and 'accuracy' will be frequently used. The definitions of "precision" and "accuracy" are:

Precision of a variable is the degree to which it is reproducible, with nearly the same value obtained each time the variable is measured.

Accuracy of a variable is the degree to which the measured value represents the true value.

6.3.1 Familiarisation of Tooth Wear Patterns

Patterns and degrees of tooth wear were learned during an initial period of the study. This learning process was undertaken on mandibles from the Edinburgh University Turner collection which would not be used in the main study. The training was repeated over several weeks until agreement was reached on tooth wear pattern descriptions.

In the first instance it was decided, as a result of the literature review, that the patterns and degrees of tooth wear described by Brothwell (1981) would be suitable as a learning tool (Table 2).

Table 2: Occlusal Tooth Wear Patterns Scores

Score	Description of Wear
0	No wear.
1	Enamel facets. No dentine exposed
2	Dentine exposed on buccal cusps. Area < 1 mm.
3	Dentine exposed on buccal and lingual cusps. Area < 1 mm.
4	Dentine exposed. Area > 1 mm.
5	Dentine exposed. Areas confluent.

6.3.1.1 Intra Observer Reliability:

Aim: To assess how reliable assessments were at different time periods, the weighted kappa test was undertaken.

Ten skulls were chosen by a second person. These were numbered by the second person but all numbering and any other identification marks were obscured by wrapping the mandible in tin foil so that only the occlusal surfaces of the teeth were visible (Figure 3 & Figure 4). The mandibles were then placed on the examination table ordered from 1 to 10. Only the second person knew the 'mandible number' which related to this sequence. The wear patterns on the mandibular first and second molars were recorded using Brothwell's method. Thus each mandible in the sequence was given a 'score'. This was designated as Sequence A. After a period of three weeks, the same skulls were arranged by the second person in a different sequence, designated as sequence B. Scores for Sequence A & B were obtained (Table 3).

Table 3: Intra-Observer Scoring of Occlusal Tooth Wear Patterns

Skull No	M1 Sequence A	M1 Sequence B	M2 Sequence A	M2 Sequence B
1	3	3	2	2
2	5	5	4	4
3	3	3	2	2
4	3	4	3	3
5	2	2	2	2
6	4	4	3	3
7	5	5	5	5
8	3	4	2	3
9	2	2	2	2
10	5	5	4	4

Figure 3: Top view of Wrapped Mandible with Visible Occlusal Surface of Left Lower Molars

Figure 4: Wrapped Mandible with Visible Occlusal Surface of Left Lower Molars

Sequences A and B were then compared. This was repeated until a high agreement was achieved between sequences. "Weighted Kappa", quantifying intra-rater agreements was calculated using the GraphPad QuickCalcs Web site: http://www.graphpad.com/quickcalcs/kappa1/cfm (accessed December 2012) was used to perform these statistics.

The agreement between Sequences A & B for scoring occlusal surface tooth patterns were analysed using "weighted Kappa" as follows:

a. Sequences A v Sequences B of Scoring Occlusal Surface Tooth Wear Patterns of M1:

Table 4: Agreement between Sequence A & B of Scoring of the Occlusal Surface Tooth Wear Patterns of the of M1

Sequence B / Sequence A	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Total
Score 0	0	0	0	0	0	0	**0**
Score 1	0	0	0	0	0	0	**0**
Score 2	0	0	2	2	0	0	**4**
Score 3	0	0	0	2	0	0	**2**
Score 4	0	0	0	0	1	0	**1**
Score 5	0	0	0	0	0	3	**3**
Total	**0**	**0**	**2**	**4**	**1**	**3**	**10**

Number of observed agreements: 8 (80.00% of the observations).

Number of agreements expected by chance: 2.6 (26.00% of the observations).

Weighted Kappa=0.851.

The strength of agreement was considered to be "very good".

b. Sequences A v Sequences B of Scoring Occlusal Surface Tooth Wear Patterns of M2:

Table 5: Agreement between Sequence A & B of Scoring of the Occlusal Surface Tooth Wear Patterns of M2

Sequence B / Sequence A	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Total
Score 0	0	0	0	0	0	0	**0**
Score 1	0	0	0	0	0	0	**0**
Score 2	0	0	4	1	0	0	**5**
Score 3	0	0	0	2	0	0	**2**
Score 4	0	0	0	0	2	0	**2**
Score 5	0	0	0	0	0	1	**1**
Total	**0**	**0**	**4**	**3**	**2**	**1**	**10**

Number of observed agreements: 9 (90.00% of the observations).

Number of agreements expected by chance: 3.1 (31.00% of the observations).

Weighted Kappa=0.909.

The strength of agreement was considered to be “very good”.

6.3.1.2 Inter Observer Reliability

Aim: To evaluate the reproducibility of the scoring method between observers.

This time ten skulls were chosen by a second observer. They were numbered by the second observer, but all numbering and any other identification marks were obscured by wrapping the mandible in tin foil, as before, so that only occlusal surfaces of teeth were visible (Figure 3 & Figure 4). The mandibles were then placed on the examination table ordered from 1 to 10 (Sequence A). Only the second observer knew the 'mandible number' which related to this sequence.

The wear patterns on mandibular first and second molars were recorded, was scored independently by two observers, the author plus one other. The two sets of scores were then compared.

Three weeks later, the same skulls were arranged by the second person in a different sequence (Sequence B), again only the occlusal surfaces being visible. Scores for Sequence B were obtained by two observers.

Sequence A & B were then compared. Scores recorded by the two observers were required to be almost identical for agreement criteria to be met. This was repeated until a high level of agreement was achieved between sequences (Table 6). Weighted Kappa was used, to compare results of both assessors.

Table 6: Inter-Observer Scoring of Occlusal Tooth Wear Patterns

Skull No	M1 Sequence A	M1 Sequence B	M2 Sequence A	M2 Sequence B
1	5	5	5	4
2	3	3	2	2
3	5	5	5	5
4	2	3	2	2
5	3	3	2	2
6	3	3	2	2
7	5	5	4	4
8	3	3	2	2
9	4	3	3	4
10	4	4	3	3

The agreement between Sequences A & B for scoring occlusal surface tooth patterns were analysed using Weighted Kappa as follows:

a. Sequences A v Sequences B of Scoring Occlusal Surface Tooth Wear Patterns of M1

Table 7: Agreement between Sequence A & B of Scoring of the Tooth Patterns of the Occlusal Surface of M1

Sequence B / Sequence A	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Total
Score 0	0	0	0	0	0	0	**0**
Score 1	0	0	0	0	0	0	**0**
Score 2	0	0	0	1	0	0	**1**
Score 3	0	0	0	4	0	0	**4**
Score 4	0	0	0	1	1	0	**2**
Score 5	0	0	0	0	0	3	**3**
Total	**0**	**0**	**0**	**6**	**1**	**3**	**10**

Number of observed agreements: 8 (80.00% of the observations).

Number of agreements expected by chance: 3.5 (35.00% of the observations).

Weighted Kappa=0.804.

The strength of agreement was considered to be "very good".

b. Sequences A v Sequences B of Scoring Occlusal Surface Tooth Wear Patterns of M2

Table 8: Agreement between Sequence A & B of Scoring of the Tooth Patterns of the Occlusal Surface of M2

Sequence B / Sequence A	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Total
Score 0	0	0	0	0	0	0	**0**
Score 1	0	0	0	0	0	0	**0**
Score 2	0	0	5	0	0	0	**5**
Score 3	0	0	0	1	1	0	**2**
Score 4	0	0	0	0	1	0	**1**
Score 5	0	0	0	0	1	1	**2**
Total	**0**	**0**	**5**	**1**	**3**	**1**	**10**

Number of observed agreements: 8 (80.00% of the observations).

Number of agreements expected by chance: 3.2 (32.00% of the observations).

Weighted Kappa=0.836.

The strength of agreement was considered to be "very good".

Conclusions:

The intra and inter observer reliability testing indicated that tooth wear assessment at different time periods and between different assessors was precise to the extent that it could be used in age assessment methods.

6.3.2 Confirmation of Validity of Age Estimation by Tooth Wear Patterns Using Skulls of Known Age

Several authors (Nowell, 1978; Brothwell, 1981; Kieser *et al.*, 1983) have cautioned that tooth wear patterns appraised in one population should not be used to assess age in another population or era. (Brothwell, 1981) The problem of complying with the implication of this statement is that a sufficient number of skulls aged between 6 and 18 years old, aged by eruption dates, is seldom available in any one population collection, and therefore not available to create a juvenile "known age" group as recommend by Miles (1962). It has previously been stated that aging of the populations to be used in the main study was a prerequisite, so that age related growth, if occurring, can be accounted for in the measurements taken on the skulls. However, none of the three populations of unknown age were aged 6 to 18 as assessed by tooth eruption dates, which would allow a Miles-type assessment of early tooth wear to be used and extrapolated to older age groups.

However, 60 skulls of known age were available. Using some of these skulls, and carrying out a blind study as explained below, the validity of ageing skulls by tooth wear patterns was assessed.

6.3.2.1 Validation of Miles Chart Using Skulls of Known Age:

In this section, the ages of 50 Chinese skulls were estimated using tooth wear patterns as described in the Miles' Chart and then compared with their actual recorded age as follows.

Aim: To validate the Miles Chart and its efficacy age assessment.

Method:

Fifty Chinese mandibles from the Turner Collection, Anatomy Section, Department of Biomedical Sciences in the College of Medicine, University of Edinburgh were chosen at random by an independent colleague. These Chinese skulls were of documented age.

The criterion for selection was an intact molar dentition in the upper and lower jaws [two premolars and three molars] on the left side of the dental arch and both arches were shown to be in occlusion. In seven cases, teeth on the right side were used to compensate for post-mortem tooth loss on the left side. All Chinese skulls included in this preliminary study were recorded as male; therefore sexual dimorphism could not be investigated or could have played a role in the results.

All the skulls had an identification mark placed at the time of deposition of the skulls in the museum, and this matched the recorded date at death. A colleague obscured all these identification marks on the skulls by wrapping the mandible in tin foil, so that only the teeth occlusal surfaces were visible (Figure 3 & Figure 4). The skulls were then laid out, numbered 1 to 50, called the table number. The mandibular teeth were cleaned with non-alcoholic material to make sure that all details of wear were clear. A hand held 70mm Magnifying Glass with Light, 3X magnification (Rolson, Ruscombe, Twyford, Berkshire, United Kingdom) was used to evaluate tooth wear patterns.

A newly devised "age calculator" was used, based on Miles Chart. This 'tool' consists of:

1. A blank record card (Figure 5) one for each of the 50 teeth. On this card, the sequence number is recorded as well as the [eventual] estimated age.
   There are diagrams of two blank teeth [occlusal surfaces] on which the tooth wear patterns are drawn. On the right side, there is an aid to show the colours used to illustrate the patterns, and spaces for the skull number and actual age, to be filled in at the end of the exercise. During the assessment, these are blank (Figure 5).
2. A transparent sheet, with a vertical red line, can be placed over the completed record card. In the illustration (Figure 6) the red line has been aligned with M1.
3. The Miles chart, is placed between the record card and the transparent sheet (Figure 6). This is moved horizontally until the recorded wear pattern on the record card corresponds with a similar pattern on the Miles chart (Figure 1).

The wear patterns of M1 & M2 for each tooth are recorded on the record card in the appropriate boxes. The transparent sheet is overlaid and the Miles chart inserted between the two. The chart is moved until the recorded pattern corresponded with a similar pattern on the Miles chart. When there was doubt about the tooth wear patterns, the age was always assessed upwards. This process was repeated for M2. An example of a completed card, after assessment, is shown in Figure 7.

The functional age of M1 & M2 was then translated to age at death in years, and in addition, the mean (M1 + M2) age at death was calculated. A record card for each tooth was made (Figure 5) and this was attached to a transparent sheet on which was drawn a "recording line".

Only after all the 50 records were complete was the skull number and actual age filled in on the record card by the colleague. Then the estimated age according to M1, M2 and the mean estimated age, were compared to the actual age, using the Bland-Altman statistical method (Bland & Altman, 1986).

A Bland-Altman plot approach was performed using GraphPad Prism version 6.01 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com was used to compare these statistics. This was recommended by a professional statistician.

Figure 5: Record Card of Tooth Wear Pattern

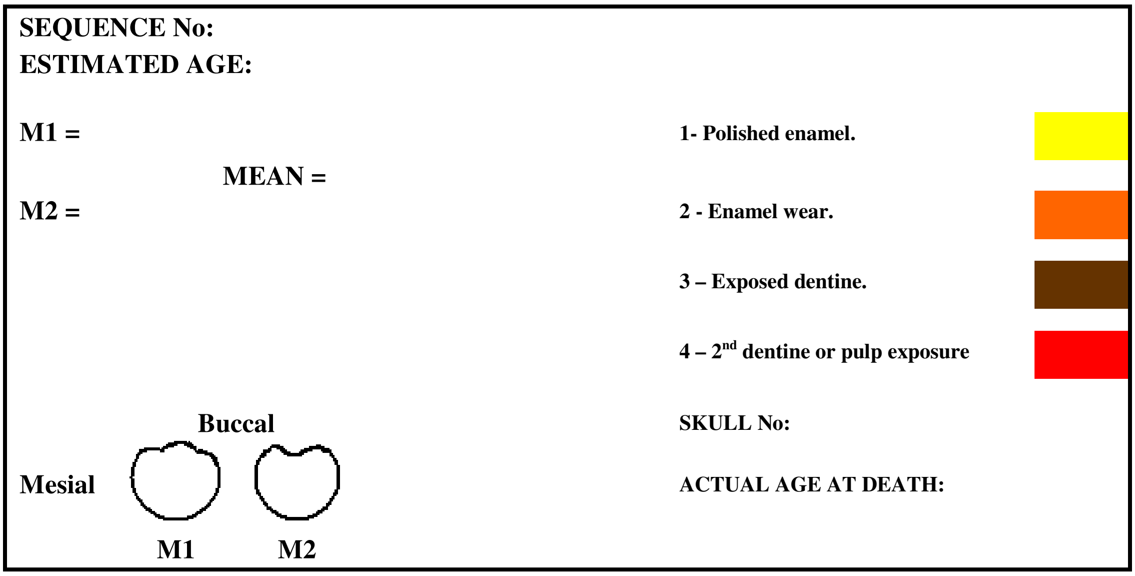


Figure 6: Age Calculator with Miles Chart

SEQUENCE No:
ESTIMATED AGE:

M1 =

MEAN =

M2 =

1- Polished enamel.

2 - Enamel wear.

3 – Exposed dentine.

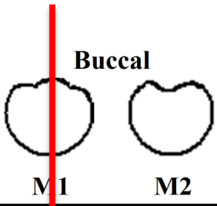
4 – 2nd dentine or pulp exposure

SKULL No:

ACTUAL AGE AT DEATH:

Buccal

Mesial



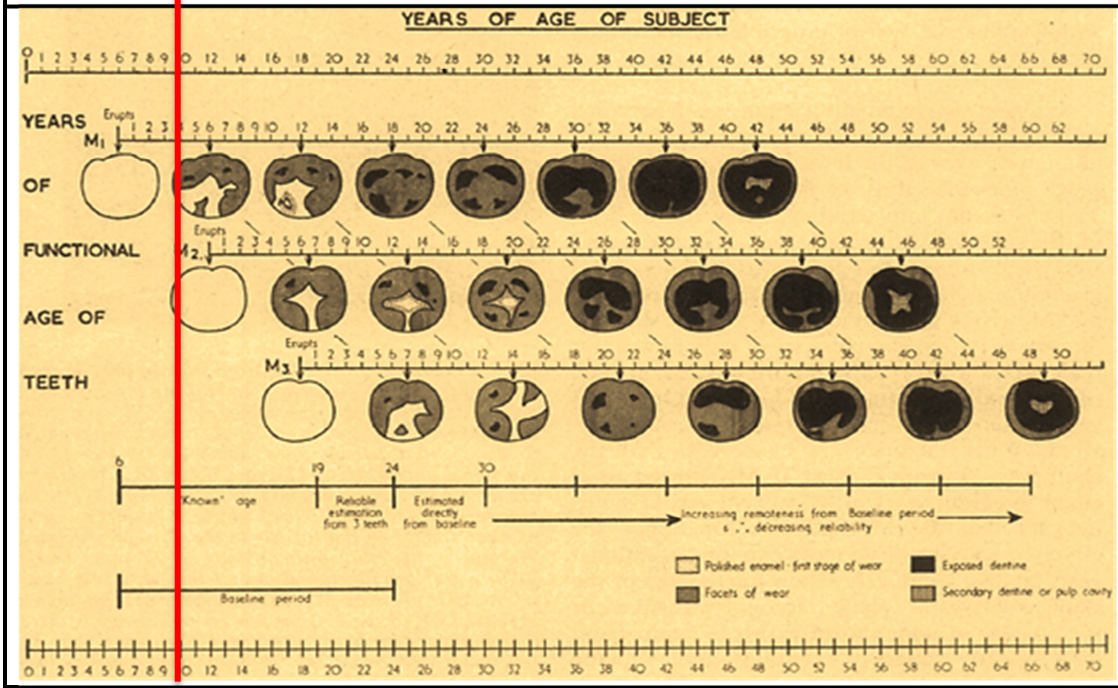
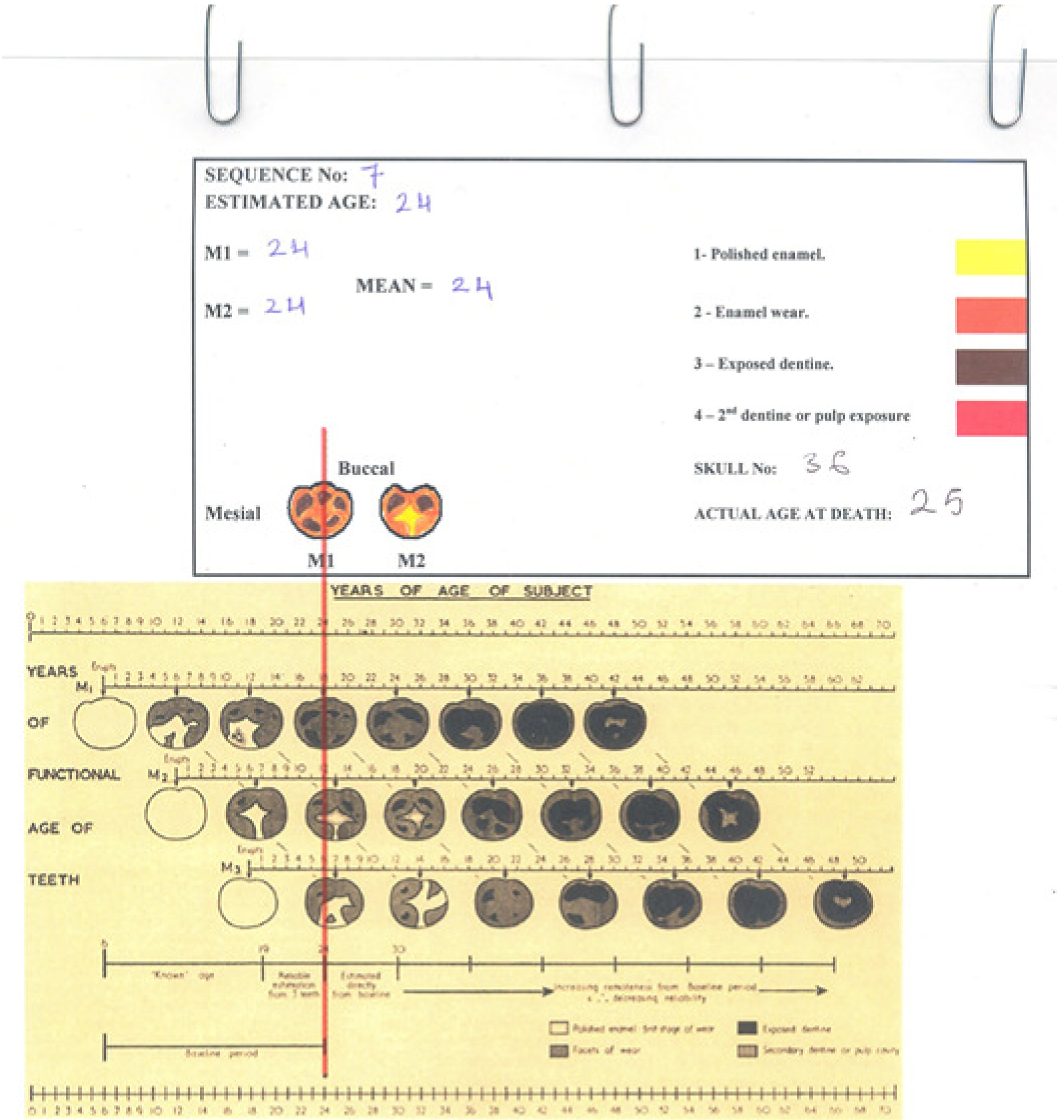


Figure 7: Calculator (Miles Chart) with Completed Record Card



Results

The raw data is given in Appendix 1, Table 1.

The agreement between the estimated age of the first molar (M1), second molar (M2) and the average of M1 & M2 and the actual age of the Chinese skulls were analysed using Bland-Altman Plots as following:

Actual Age vs. Estimated Age (M1)

Figure 8: Bland-Altman Plot of Actual Age and Age Estimated from M1 (in years)

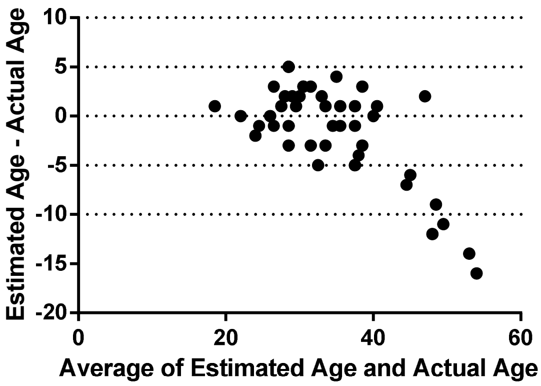


Figure 8 shows that there is relatively good agreement between the estimated and actual age. Approximately ~ 86% of estimated ages lay between ±5 years. In skulls 45 years or older, the accuracy of aging is less, and under estimated.

Actual Age vs. Estimated Age (M2)

Figure 9: Bland-Altman Plot of Actual Age and Age Estimated from M2 (in years)

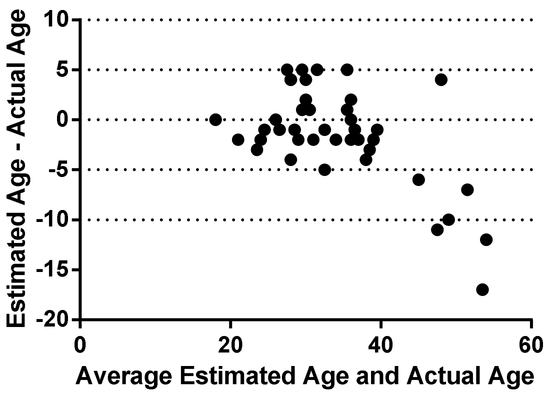


Figure 9 shows that there is a relatively good agreement between the estimated and actual age. Approximately ~ 88% of estimated ages lay between ±5 years. Once again, the estimation and the accuracy of ages is less and under estimated in skulls aged 45 years or older.

Actual Age vs. Average Age (M1 & M2)

Figure 10: Bland-Altman Plot of Actual Age and Calculated as Average Age Estimated from M1 & M2 (in years)

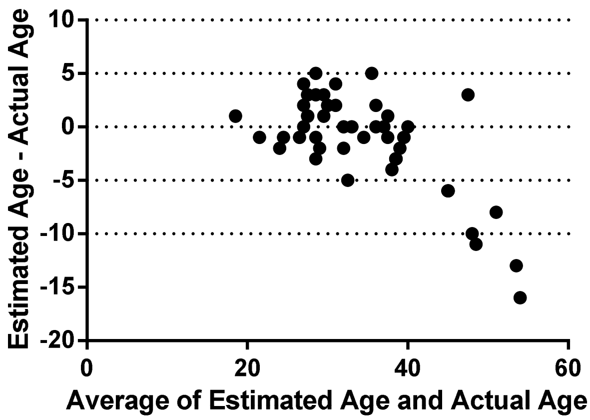


Figure 10 shows that there is a relatively good agreement between the estimated and actual age. Approximately ~ 88% of estimated ages lay between ±5 years. Once again, estimation and the accuracy of ages is less and under estimated in skulls aged 45 years or older.

Summary of Results

Using the Miles chart, M1, M2 and means of M1+M2 all allow circa 86% of cases to be allocated within ± 5 years of their actual age.

Accuracy diminishes when skulls are over 40 years of age at death.

Discussion

The Bland-Altman plot was used to analyse the data to see how close the estimated ages corresponded to the actual ages. This statistical method was devised because the use of correlation was considered inadequate and misleading (Bland & Altman, 1986). The Bland – Altman plot has the further advantage in that the spread of this correlation can be visually identified and can be seen to lie within either a ± 5 years or a ± 10 years span.

It is seen that about 86% of estimated ages corresponded with actual age, within ± 5 years, and about 92% within ten years. The charts also illustrate how the estimated ages are underestimated after about 40 years of age. It can be concluded that age estimation using tooth wear patterns is considered to be fairly accurate in young individuals up to 40 years old but the accuracy decreases with age, because of difficulty in assessing levels of tooth wear in older individuals. This is consistent with many previous studies (Miles, 1958; Johnson, 1976; Helm & Prydso, 1979).

In conclusion, Miles chart can, with caution, be used to arrive at a reasonable estimation of age in this Chinese population.

6.3.2.2 Validation of Brothwell Chart Using Skulls of Known Age

In this section, the age of the Chinese skulls was estimated using the Brothwell Chart to ascertain if this would be a satisfactory method of assessment to use in the main study.

Aim: To validate the Brothwell Chart and its usefulness in age assessment.

Method:

An independent colleague randomly chose 50 mandibles from Chinese skulls of known age in the Turner Collection, Anatomy Section, Department of Biomedical Sciences in the College of Medicine, University of Edinburgh.

A variation of the newly devised “age calculator” was adapted for use with the Brothwell chart. The description will not be repeated in full. The constituent parts of the “age calculator” were identical, the only differences being that the transparent sheet had two lines which ‘encompass M1 and M2’ and bracket these with similar patterns on the Brothwell’ Chart (Figure 11).

In the Brothwell chart patterns for M3 are also given. M3 was not used in this study.

Figure 12 shows a completed assessment record card with the Brothwell Chart beneath.

The selection of mandibles, and the equipment and protocol used for the assessments of age were the same as previously described on page 85 & 86.

The wear patterns of M1 & M2 from randomly selected mandibles were recorded on the record card in the appropriate boxes. The transparent sheet was overlaid and the Brothwell Chart inserted between the two. The chart was then moved until the recorded pattern of M1 and M2 corresponded with a similar age group pattern on the Brothwell Chart. When there was doubt about the tooth wear patterns, the age group was always assessed upwards.

In this way skulls were allocated to one of four age groups, 17-25 years, 26-35 years, 36-45 years and over 45 years. No attempt was made to assign a skull to an estimated age, but only to place it within an age group.

Only after all the 50 records were complete was the skull number and actual age filled in on the record card by the independent colleague.

Weighted Kappa, quantify inter-rater agreement were calculated using the GraphPad QuickCalcs Web site: http://www.graphpad.com/quickcalcs/kappa1/cfm (accessed December 2012).

Figure 11: Age Calculator with Brothwell Chart

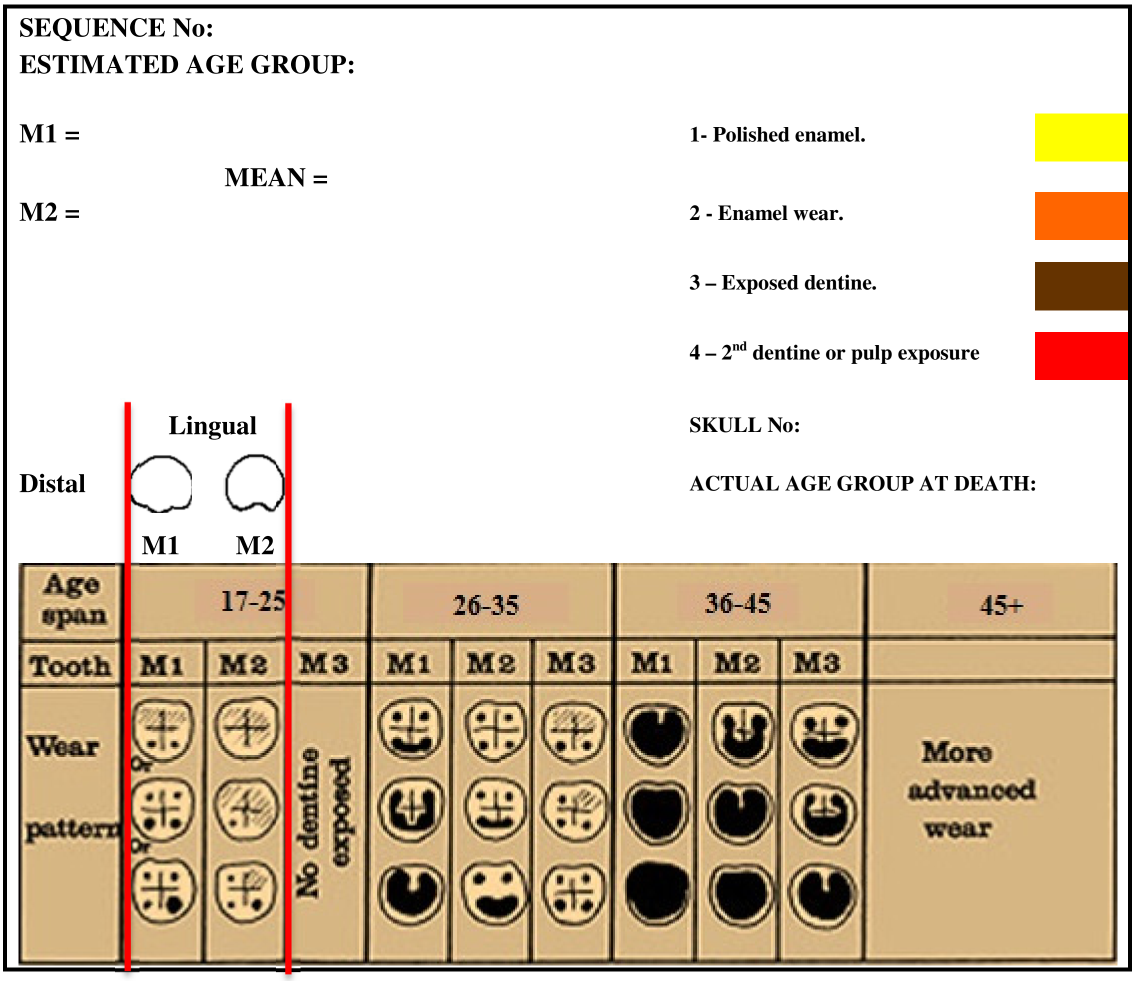
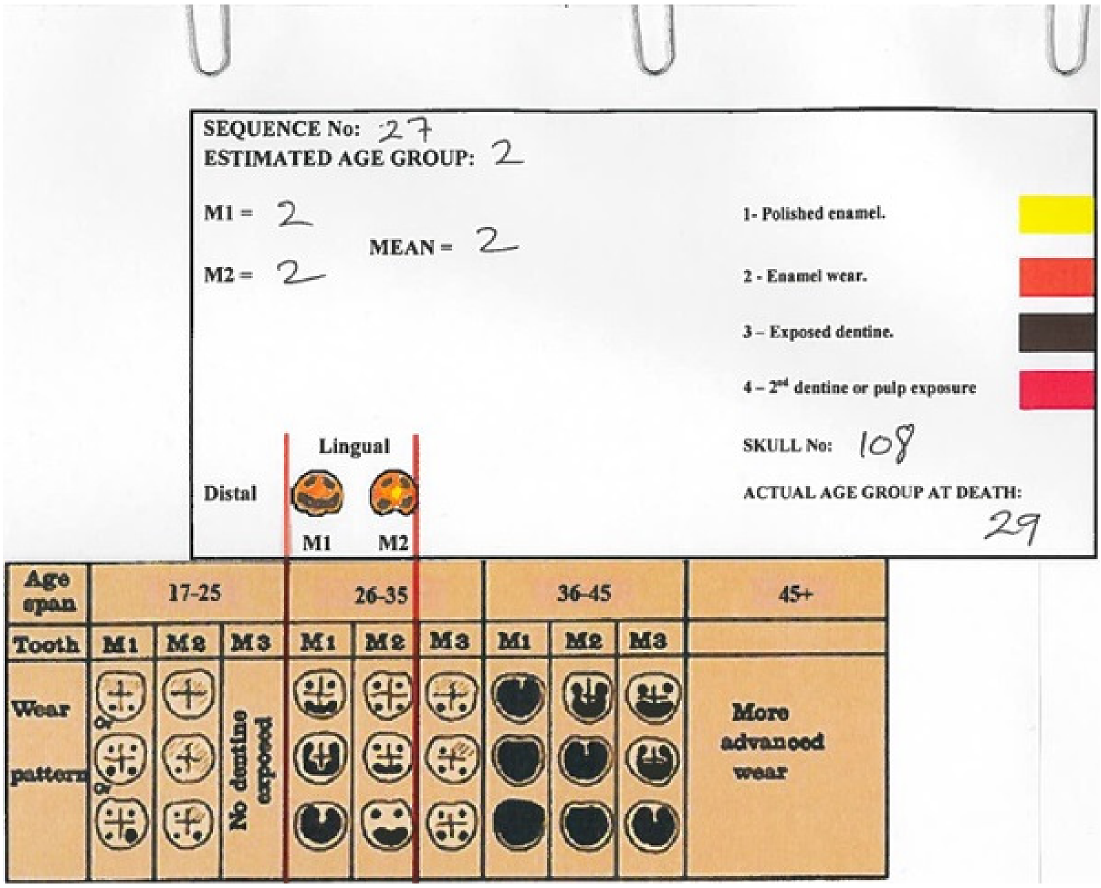


Figure 12: Calculator with Completed Record Card (Brothwell Chart)



Results

The raw data is given in Appendix 1, Table 2.

The agreement between the estimated age group and the actual age group of the Chinese skulls were analysed using Weighted Kappa as following:

Actual Age Group vs. Estimated Age Group

Table 9: Agreement between Actual and Estimated Age Groups

Estimated Age Groups / Actual Age Groups	Group 1 (17-25 yrs.)	Group 2 (26-35 yrs.)	Group 3 (36-45 yrs.)	Group 4 (> 45 yrs.)	Total
Group 1 (17-25 yrs.)	**7**	**1**	**0**	**0**	8
Group 2 (26-35 yrs.)	**0**	**21**	**3**	**0**	24
Group 3 (36-45 yrs.)	**0**	**0**	**10**	**0**	10
Group 4 (> 45 yrs.)	**0**	**0**	**2**	**6**	8
Total	7	22	15	6	50

Number of observed agreements: 44 (88.00% of the observations)

Number of agreements expected by chance: 15.6 (31.28% of the observations)

Weighted Kappa= 0.877.

The strength of agreement was considered to be 'very good'.

Discussion

Weighted Kappa was used to calculate the inter-rater agreement statistic between two measurements (Cohen, 1968). This was used rather than the Bland-Altman test previously used, as the weighted Kappa assesses the agreement when rating is done on categorised or ranked order information rather than continued information. In this part of the study, close matching was always achieved. Skulls were always allocated either to the correct age group [most cases] or to an adjacent group, but never to a group non-adjacent.

The age groups were changed to be 17–25 years, 26–35 years, 36–45 years and > 45 years, to eliminate the possibility of having 26 year olds and 36 year olds being in two different groups, as occurs in the original Brothwell Chart. The strength of agreement between the actual age group and estimated age group was considered to be good.

It has been argued that the accuracy of age estimation was increased (Johnson, 1976; Kim *et al.*, 2000) if skulls were categorised into age groups rather than given a 'specific age'. This has not been verified in the current preliminary studies where the results show that the agreements between the actual age and the estimated age of ± 5 years, using Miles' method, and between the actual age group and the estimated age group using Brothwell's method are very similar.

6.3.2.3 Overall Conclusions

The above results show that the charts of both Miles and Brothwell based on tooth wear can be used as a fair method of age assessment. In the main study, it is consider sufficient, for age related growth changes, to divide the skulls into four groups rather than age individual skulls, therefore the decision was taken to use the Brothwell Chart to age the Indian and British skulls in the main study. This allowed for easier and more rapid data collection with no loss of overall accuracy.

6.3.3 Age Assessment of Indian and British Skulls Using the Brothwell Technique

The previous preliminary studies showed that tooth wear patterns were readily and consistently identified, both at inter and intra-observer levels. The ages of the Indian and British skulls which were used in the present study were unknown and because age may be hypothesised to be related to growth and the position of the maxillofacial foramina, it was considered necessary to assess the age of Indian and British skulls.

The ages of the Indian and British populations used in the main study were therefore assessed using the age calculator based on the Brothwell Chart, which places skulls into four age groups.

6.3.3.1 Method

All Indian and British skulls were considered to be adult because in every skull at least one third molar tooth was fully erupted.

Age estimation of the Indian and British skulls using the Brothwell Chart was carried out in the following manner. Sixty skulls from the Turner Collection, Anatomy Section, Department of Biomedical Sciences in the College of Medicine, University of Edinburgh, were used. Thirty were Indian skulls, catalogued as 'Hindu from River Hoogley, Calcutta', thirty were British skulls catalogued as being either Anglo-Saxon (English) or Dark Ages (Scottish). They all exhibited zero caries and low post-mortem tooth loss, and had similar wear patterns to the Chinese cohort previously described.

The selection of mandibles, and the equipment and protocol used for the assessments of age were the same as previously described on page 85, 86 & 93.

The age was always assessed upwards in case of doubt about the tooth wear patterns because the result of this study and other results confirmed that the aging by tooth wear pattern usually underestimates the age of subjects especially in subjects over the age of 45 years.

Results: The age estimation results of Indian and British skulls are presented in Appendix 1, Table 3.

6.3.4 Distribution of the Age Groups within Each Population

Results of age grouping show that the Indian and British population were distributed into the four age groups as shown in Figure 13, 14.

Figure 13: Distribution of Indian and British Populations Skulls According to Four Age Groups

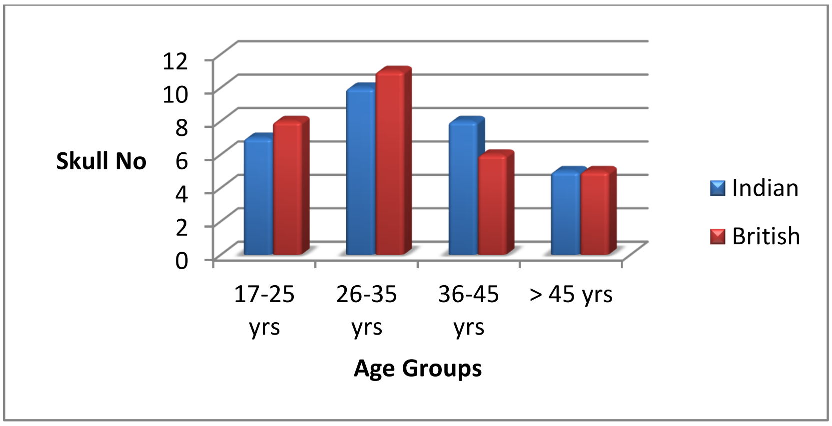


Figure 13 shows that there is a relatively even distribution among the four age groups.

Figure 14: Distribution of Four Populations Skulls According to Four Age Groups

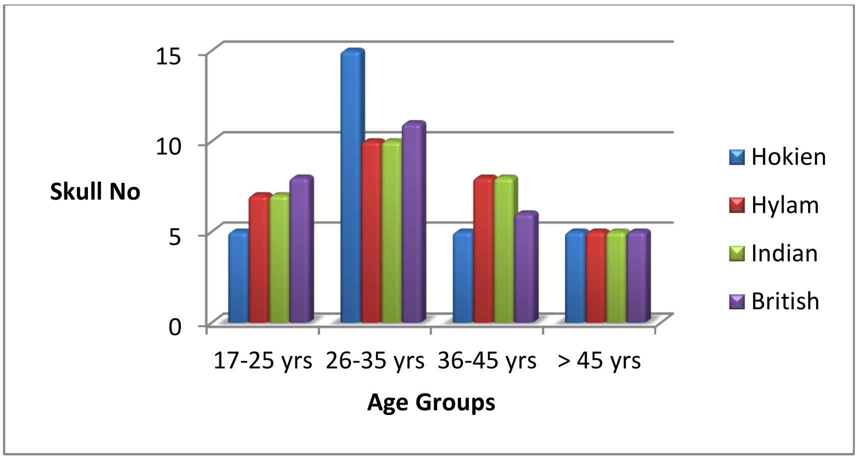


Figure 14 shows the distribution when the Chinese groups, used in the main study, are added. Again, the distribution is fairly even among groups.

6.4 Conclusion

When the age of Indian and British skulls were estimated and placed into one of four "age groups", it was shown that the distribution of ages was similar in each of the two populations.

Also, when the Chinese populations, of known age, were "grouped", they also had a similar age distribution to the Indian and British populations.

These four age groups were considered appropriate, being of equal distribution, to allow valid statements to be made regarding age related growth, in the main study.

Chapter 7

Methods Used In the Main Study

7.1 Subjects

Skulls from three populations, Chinese, Indian and British, were obtained from the Turner Collection, Anatomy Section, Department of Biomedical Sciences in the College of Medicine, University of Edinburgh. The Chinese skulls had been collected by Gordon Harrower when Professor of Anatomy, National University of Singapore. They were subsequently donated by him to the Department of Anatomy, University of Edinburgh (Now known as the Section of Anatomy).

The sample consisted of 60 Chinese skulls, 30 Indian skulls and 30 British skulls. The sex and the age at death of each of the Chinese skulls were known, having been recorded at the time of acquisition (Gordon, 1928). The age range was from 18 to 62 years. Only two of the Chinese skulls were females and these were excluded, leaving 60 male skulls. The Chinese skulls were recorded as being 30 Hokien and 30 Hylam Chinese. The Hokien people lived in Fujian Province which is located in southern China (Figure 15). The Hylam people originated from the island of Hainan (Figure 16) off the Chinese coast.

The Indian and British skulls were catalogued as being of unknown age. The Indian cohort was recorded as "Hindu from River Hoogley, Calcutta". The British cohort was recorded as being either Anglo-Saxon (English) or Dark Ages (Scottish).

Figure 15: Show the Respective area of Origin of the Hokien People

Fujian (Hokien)

Figure 16: Show the Respective area of Origin of the Hylam People

Hainan (Hylam)

7.2 Definitions of the Anatomical Landmarks Used In the Study.

Tables 10, 11, 12 and 13 give the definitions of the measured distances relating to the supraorbital, infraorbital, mental and mandibular foramina.

The word "distance" was used to indicate the shortest measurement between any two points using an electronic digital calliper in the direct measurement method and the "ruler" tool in the scanning measurement method, and did not take into consideration the curvature of the skull.

Tables 14, 15, 16 and 17 define the points used to delineate these distances.

Table 18 defines the anatomical lines on which points were placed.

The tables show the codes which were used for each point, distance or line, and the codes are used throughout the thesis, and should be read in conjunction with Figure 17 & 18, pp. 106 & 107.

Table 10: Distance Definitions Related to the Supraorbital Foramen

Distance	Definition of Distances
D1A	The distance between the **P1A** on the right side and the **P1A** on the left side.
D1B	The distance between the **P1A** and the **P1B.**
D1C	The distance between the **P1A** and the **P1C.**
D1D	The distance between the **P1A** and the **P1D.**
D1E	The distance between the **P1E** on the right side and the **P1E** on the left side.

Table 11: Distance Definitions Related to the Infraorbital Foramen

Distance	Definition of Distances
D2A	The distance between the **P2A** on the right side and the **P2A** on the left side.
D2B	The distance between the **P2B** and the **P1B.**
D2C	The distance between the **P2C** and the anterior nasal spine.
D2D	The distance between the **P2A** and the **P2D**.
D2E	The distance between the **P2A** and the **P2E.**
D2F	The distance between the **P2A** and the **P2F**.
D2G	The distance between the **P1A** and the **P2G.**
D2H	The distance between the **P1A** and the **P2B.**

Table 12: Distance Definitions Related to the Mental Foramen

Distance	Definition of Distances
D3A	The distance between the **P3A** and the **P3B**.
D3B	The distance between the **P3A** and the **P3C**.
D3C	The distance between the **P3A** and the **P3D**.

Table 13: Distance Definitions Related to the Mandibular Foramen

Distance	Definition of Distances
D4A	The distance between the **P4A** and the **P4G.**
D4B	The distance between the **P4A** and the **P4B**.
D4C	The distance between the **P4A** and the **P4C.**
D4D	The distance between the **P4A** and the **P4D.**
D4E	The distance between the **P4A** and the **P4E**.
D4F	The distance between the **P4A** and the **P4F:** (0) if **P4F** on the **L4A**, (+) if **P4F** above the **L4A** and (-) if **P4F** below the **L4A**.
D4G	The distance between the **P4D** and the **P4E**.
D4H	The distance between the **P4D** and the **P4H**.
D4K	The distance between the **P4E** and the **P4F**.

Table 14: Anatomical Landmarks Related to Supraorbital Foramen

Point	Definitions of the Anatomical Landmarks used when taking measurements
P1A	The most medial point of the supraorbital foramen.
P1B	The point where a line drawn horizontally medially through the **P1A** intersects a line drawn vertically upward through the nasion and internasal suture.
P1C	The point where a line drawn horizontally laterally through the **P1A** intersects the temporal crest.
P1D	The point where a line drawn vertically downward through the **P1A** crosses the supraorbital rim.
P1E	The most laterally positioned point on the fronto-zygomatic suture.

Table 15: Anatomical Landmarks Related to Infraorbital Foramen

Point	Definitions of the Anatomical Landmarks used when taking measurements
P2A	The most medial point of the infraorbital foramen.
P2B	The point where a line drawn vertically upward through the **P2A** crosses the line **L1B**.
P2C	The point where a line drawn vertically downward through the **P2A** crosses the **L2C**.
P2D	The point where a line drawn horizontally medially through the **P2A** intersects the facial midline.
P2E	The point where the zygomatico-maxillary suture intersects the infra orbital rim.
P2F	The point where a line drawn vertically upward through the **P2A** crosses the infraorbital rim.
P2G	The point where a line drawn vertically downward through the **P1A** crosses the **L2B**.

Table 16: Anatomical Landmarks Related to Mental Foramen

Point	Definitions of the Anatomical Landmarks used when taking measurements
P3A	It is the most medial point of the mental foramen.
P3B	The point where a line drawn horizontally forward through the **P3A** intersects a line (**L3A**) drawn vertically downward through the superior tip of the septum between the mandibular central incisors (**P3E**).
P3C	The point where a line drawn horizontally backward through the **P3A** crosses the posterior border of the ramus.
P3D	The point where a line drawn vertically downward through the **P3A** crosses the inferior border of the mandible.
P3E	It is the superior tip of the septum between the mandibular central incisors.

Table 17: Anatomical Landmarks Related to Mandibular Foramen

Point	Definitions of the Anatomical Landmarks used when taking measurements
P4A	It is the lowest medial point of the mandibular foramen.
P4B	The lowest medial point on the condylar notch (Internal surface).
P4C	The point where a line drawn horizontally through the lowest medial point on the mandibular foramen (**P4A**) crosses the posterior border of the ramus.
P4D	The point of intersection between the occlusal line **(L4A)** and the posterior border of the mandible.
P4E	The point of intersection between the **L4A** and internal oblique ridge.
P4F	The point on medial surface of the ramus where a line drawn vertically through the **P4A**, crosses the **L4A**. **P4F** = (0) if on the **L4A**, (+) if **P4F** above **L4A** and (-) if **P4F** below the **L4A**.
P4G	The point where a line drawn vertically downward through the lowest medial point on the mandibular foramen (**P4A**) crosses the inferior border of the ramus.
P4H	The point of intersection between the **L4A** and external oblique ridge.

Table 18: Line Definitions Related to the Anatomical Landmarks

Line	Definitions of the Anatomical Landmarks used when taking measurements
L1A	The line drawn vertically through the nasion and internasal suture.
L1B	The line drawn horizontally laterally through the **P1B** and the **P1A.**
L2A	The line drawn vertically through the anterior nasal spine, intermaxilary suture and prosthion point (The inferior tip of the septum between the maxillary central incisors).
L2B	The line drawn horizontally through the point **P2A** medially and laterally.
L2C	The line drawn horizontally laterally through the anterior nasal spine.
L3A	The line (**Symphysis line**) drawn vertically downward through the superior tip of the septum between the mandibular central incisors (**P3E**).
L4A	The horizontal line (**Occlusal Line**) passes on the occlusal surfaces of the first and the second molars, and then it extends horizontally posteriorly on the internal surface of the ramus.

Figure 17: Skull with Anatomical Landmarks

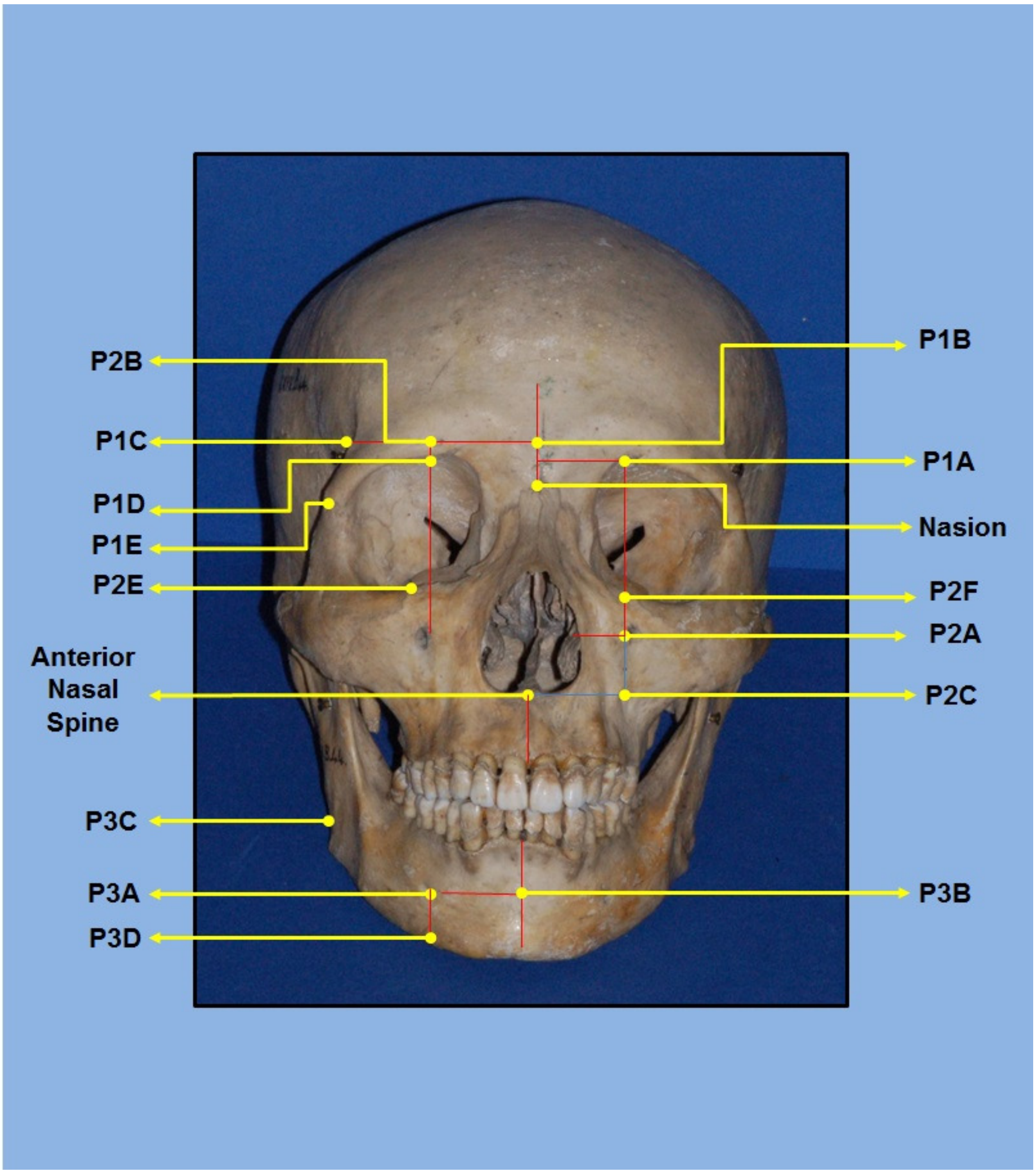
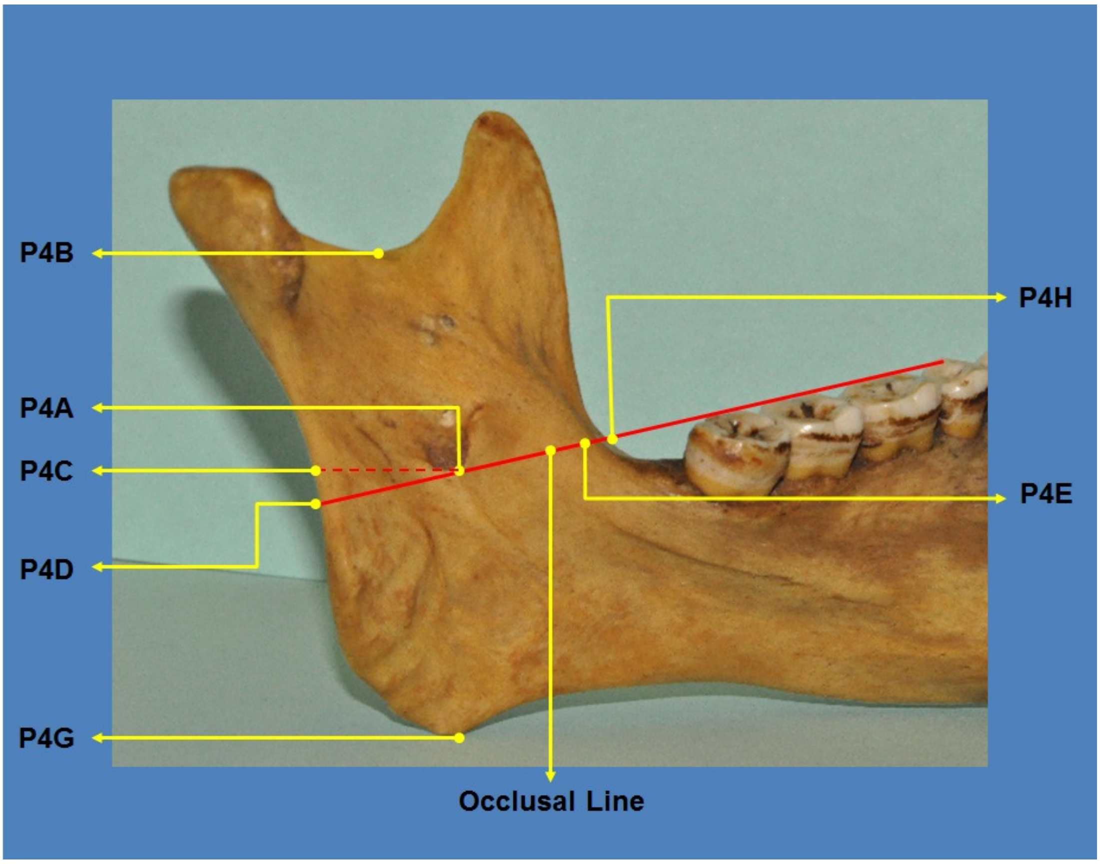


Figure 18: Mandible with anatomical landmarks



7.3 Measurement Methods

Two methods were used for obtaining data related to the above anatomical landmarks:

1. Electronic Digital Calliper method using an electronic calliper.

2. 3D Laser Scanning method.

7.3.1 Electronic Digital Calliper Method

7.3.1.1 Apparatus for Taking Electronic Calliper Measurements

Figure 19 & Figure 20 show the apparatus that was used to stabilise the crania and mandibles when taking electronic digital calliper measurements. The apparatus consisted of a rectangular horizontal platform and a hinged back plate. The platform was provided with four adjustable legs which were used to level the platform. This was checked by two spirit levels at right angles to each other.

The platform allowed the mandible to be positioned and stabilised in the standard horizontal plane as defined by Morant. " The mandible to be positioned in that horizontal plane with which contact is made at three or more points when a vertical pressure is applied to the second left molar tooth" (Morant *et al.*, 1936). The mandible, once positioned in the "horizontal plane of Morant" was held stabilised by adjusting the "carpenter square" downwards to apply pressure on the posterior molars as required by the definition.

The crania could also be stabilised but this is carried out using the "cranium stabilising bar" which could be adjusted vertically to accommodate the cranium and accomplished by bringing the bar into contact with the cranium and locking this into position. The bar was covered with a sponge to prevent damage to the bones.

The back-plate was hinged to the platform and could be adjusted to any desired position. This plate stabilised the cranium or mandible, preventing backward movement

A digital sliding electronic calliper (TRESNA®, China) capable of measuring to the nearest 0.01 mm (accuracy: ± 0.02 mm per 100 mm) was used to take measurements. The calliper was connected directly to a laptop to record and all measurements were immediately stored automatically. [All measurements in mm. to two dismal places]

Spirit levels: There are two types of spirit levels. A large spirit level (9/230 mm, magnetic spirit level) was used to check the level of the horizontal platform and the pencil holder arm and make sure that they were always in the horizontal plane.
A small spirit level with a magnetic surface was attached to the digital calliper allowing the calliper ruler to be maintained in a horizontal plane when taking measurements.

Figure 19: Apparatus of Electronic Calliper Measurements (Frontal View)

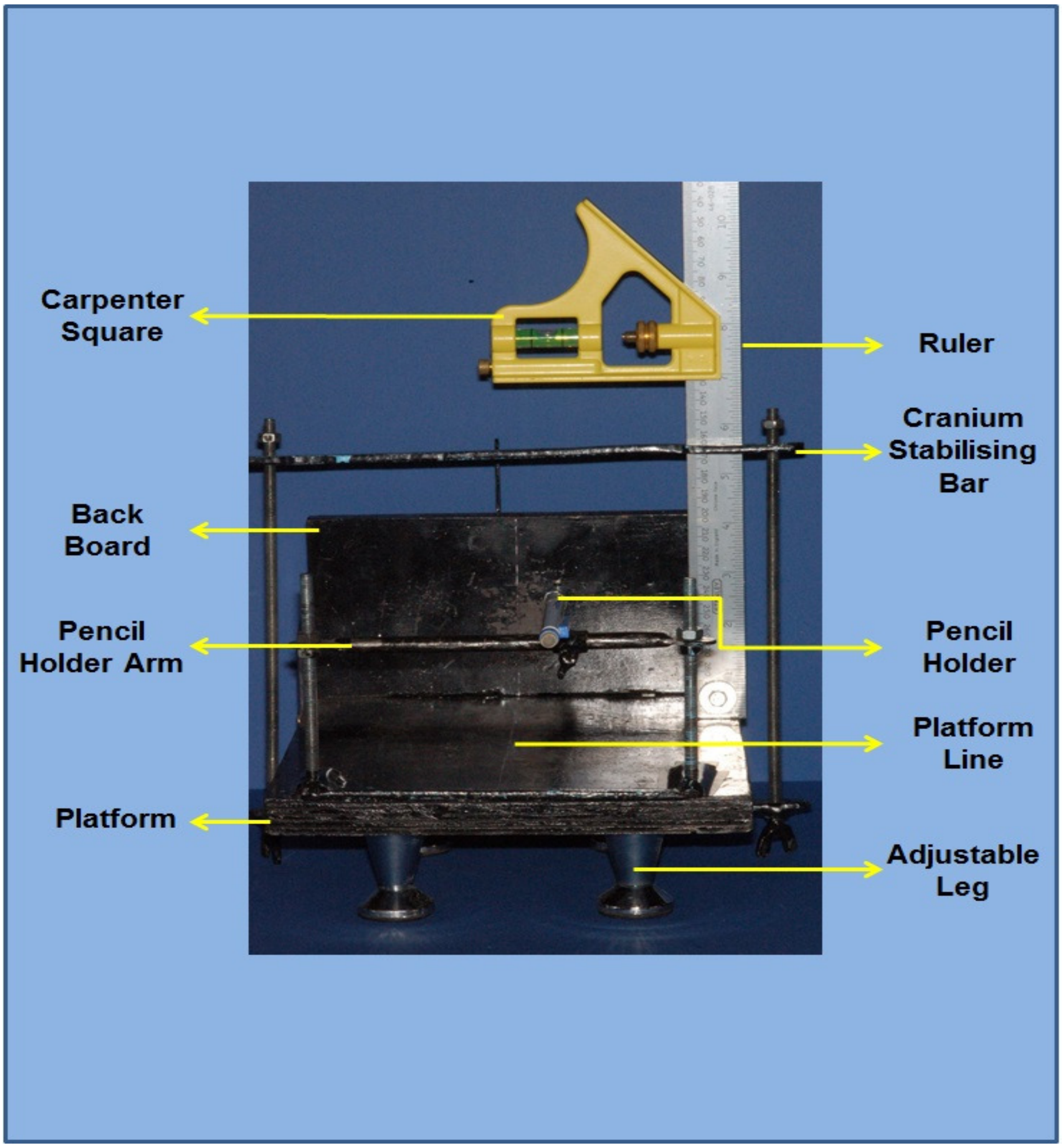
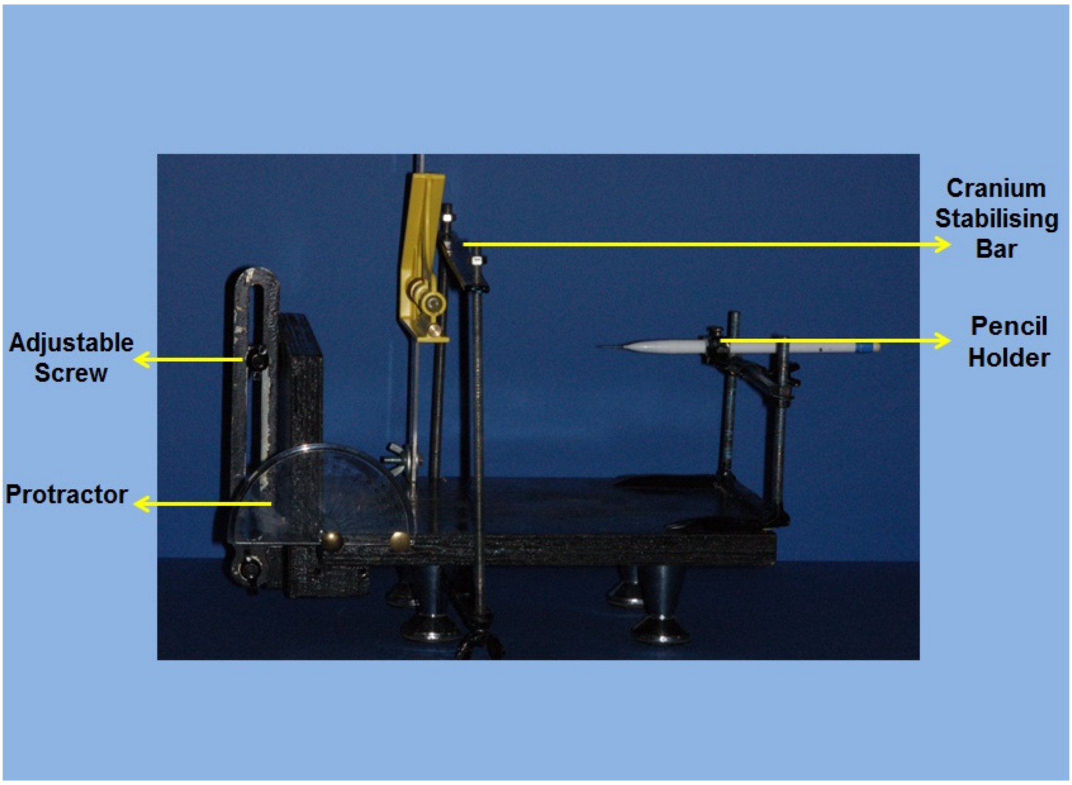


Figure 20: Apparatus of Electronic Calliper Measurements (Lateral View)



7.3.1.2 Electronic Calliper Measurement Procedure

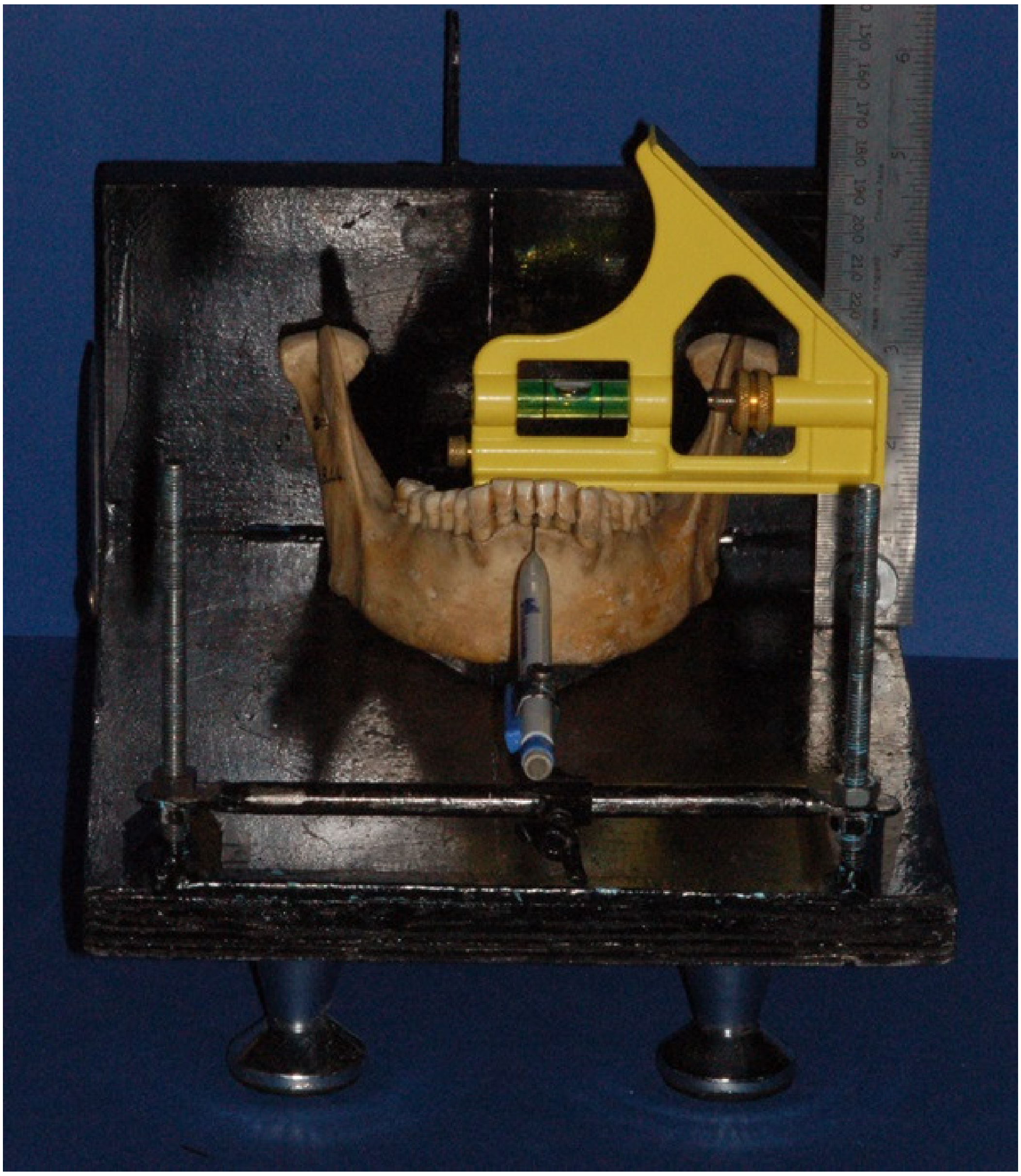
The cranium was placed on the apparatus in the standard basal position so that contacts were made by the maxillary teeth and mastoid processes or occipital condyles on the base platform (Figure 21). The back board was brought into contact with the cranium and locked to prevent posterior movement. Then the cranium was locked in this position by bringing down the "cranium stabilising bar".

Points relating to the supraorbital and infraorbital foramina were marked sequentially (Figure 17, p106), the distances between these points were measured by the electronic calliper and stored directly in the laptop.

Mandibles were placed on the apparatus platform, this time in the standard basal position, defined as "when contact is made at three or more points when vertical pressure is applied to the second left molar tooth" (Figure 22). The back board was brought into contact with the mandibular condyles and locked to prevent backward movement. As with crania, points relating to the mental and mandibular foramina were marked sequentially (Figure 18, p 107). The distances between these points were measured with the electronic calliper and stored directly in the laptop. All measurements were taken bilaterally. The distance D4A was measured by the digital calliper, whereas, the distance D4K was assessed mathematically.

Figure 21: Skull on Apparatus

Figure 22: Mandible on the Apparatus



7.3.1.3 Observer reliability

Intra observer reliability

Aim: To evaluate how reliable measurements of the distances related to the four foramina were at different time periods, the Bland-Altman Plot analysis was undertaken.

Method: Ten crania and mandibles from the anatomy collection were selected by a second person and laid out. Measurements were taken for the four foramina at two different time periods.

Results: The full data and analysis are listed in appendix as this stretches to over 10 pages. Overall the strength of agreement was considered to be “very good”.

Inter observer reliability

Aim: To evaluate how reliable were the measurements made by two different people of the distances related to the four foramina.

Method: Five crania and mandibles from the anatomy collection were selected by a third person and laid out. Both observers took measurements related to all four foramina.

Results: The full data and analysis are listed in appendix as this stretches to over 15 pages. Overall the strength of agreement was considered to be “very good”.

7.3.2 Scanning Method Using 3D Laser Scanning

7.3.2.1 Apparatus for Taking 3D Laser Scanning Measurements

FastSCAN Handheld Laser Scanner

The FastSCAN is a handheld scanner (FastSCAN SCORPION™) (Figure 23). With a simple sweep of the FastSCAN wand, instant real time 3D images and databases can be created.

FastSCAN instantly acquires three dimensional surface images when the handheld laser scanning wand is swept over an object. FastSCAN works by projecting a fan of laser light on the object while two cameras triangulate the 3D position of the laser to record cross-sectional depth profiles. The object's image is transferred to a laptop screen.

FastSCAN SCORPION™ has two cameras, allowing for more detailed scans in fewer sweeps. While scanning an object, the dual cameras on the SCORPION wand view the laser from either side to record surface profiles of the object.

An embedded FASTRAK® unit in the FastSCAN, used to determine position and orientation, allows the computer to reconstruct the full three-dimensional surface of the object in real time. The 3D data can then be exported to a host of popular 3D modelling graphic, and computer-aided design (CAD) programs, or used within the FastSCAN software.

FastSCAN is loaded with advanced features to help realize absolute precision for every scan. The system works with virtually any PC, and the software offers a full array of functions including image resizing and point of view shifting. To enable ascertaining how much data has been collected, the software incorporates a point cloud view. Moreover, raw data points, from sweeps, can be selected and deleted. The software also offers numerous scan processing features such as fine smoothing, which you can use prior to exporting the scan. Captured data is clearly displayed on screen.

Polhemus also offers Sweep Registration software, which tightens up the stitching between individual sweeps for smoother scans. Scan through glass (Refraction Correction) facilitates scanning objects.
(http://polhemus.com/?page=Scanning_Fastscan)

Figure 23: FastSCAN Scorpion (http://polhemus.com/?page=Scanning_Fastscan)

The apparatus also consists of a translucent box with walls on two sides and openings on the front and back to allow using the FastSCAN from all directions. A transmitter is placed close to the box.

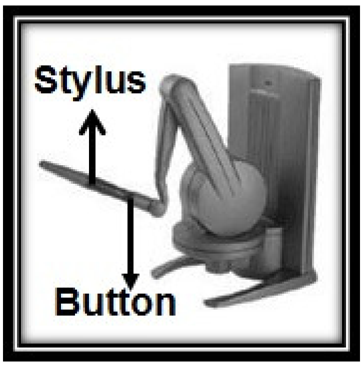
PC: A computerised 3D modelling system (FreeForm Modelling Plus™, SensAble Technologies) was used for the computerised skull measurements in the current study. The Freeform Modelling software was installed using the following: PC: Dell Precision T3500 - Intel® Xeon® CPU W3530@ 2.80 GHz - 12GB - 64 bit operating system - Windows 7 Professional.

Geomagic Software: 3D computer modelling system (FreeForm Modelling Plus™ SensAble Technologies) with haptic feedback (Phantom Desktop™) was used in this study to import the skulls to be measured into FreeForm Plus as a stereolithography (.stl) file. The strengths of the computerized modelling method are reproducibility, time conservation and little or no damage to the original specimen.

FastSCAN software gives the user a variety of options, such as adjusting scanning resolutions, linear measurements, customizing scan sweeps and controlling 3D views such as solid, wireframe or point and rotate, zoom, centre and scale.

Hardware: This system utilises PHANTOM Desktop Haptic Device (Figure 24) that enable designers and modellers to use their sense of touch to model with virtual clay, just like real clay, that provides the user with a sense of touch, when manipulating digital 3D images. The PHANTOM Desktop haptic devices are true 3D interfaces with force feedback; it delivers higher fidelity, stronger forces, and lower friction. Haptic devices are used in forensic investigations, also virtual sculpting laparoscopy training etc., engaging tactile senses to shape and manipulate digitized 3D models in a non-invasive manner.

Figure 24: PHANTOM Desktop



7.3.2.2 Laser Scanning Measurement Procedure

Scanning Cranium or Mandible

The handheld laser scanner was used to digitise the complete 3D surface of either the cranium or mandible and the data were saved in industry standard formats to be used by other programs. 3D scans of either the cranium or mandible were created with a FastSCAN™ Scorpion laser surface scanner. The object was securely positioned on the translucent box. Scanning was performed in dim light. The FastSCAN™ software filters each scan.

Profile smoothing was set to "low" (option being low, medium or high), to avoid loss of detail. Wand sensitivity was set at 1.5 (from a scale of 1 (minimum sensitivity) to 6 (maximum sensitivity)) to preserve maximum obtainable detail without unwanted artefacts (Polhemus, 2007).

Scanning a 3D object required multiple sweeps which were "registered" while processing, and allowed amendment of small errors in scan sweep alignment (Polhemus, 2007).

A "basic surface" was generated to merge sweeps smoothly. Parameters controlling this function are available within "Generate Surface".

"Smoothing" option controlled the extent to which each individual sweep "stitches" one into another (set at 1.0).

The "decimation" value, which affects the triangulation detail of the scan and subsequent file size, was set to 0.5. Completed scans were exported as .stl (stereolithography) files, and then the data was saved in industry standard formats to be used by other programs.

Reconstructing the Scan in Freeform Modelling Plus™

The .stl file was imported into FreeForm Modelling Plus™.

The 3D software integrated a PHANTOM™ desktop arm and a haptic feedback device that allowed the user to have a "sense of touch".

The scan was subsequently re-designated as a FreeForm™ .cly file (SensAble Technologies™, 2002).

From the "File" menu, FastSCAN™ file was imported to FreeForm™, in Dynabar (Figure 25) an option available to "fill holes" in the 3D image. The "fill holes" option was selected by clicking on the down arrow at the fill Style.

Other option to "Add fine detail" could be elected by pressing the down arrow at the Clay Coarseness.

In Impact as, ensures that "Clay" option was chosen.

Also ensure that the "Align Voxel Crid with Model" box was ticked.

Then click [Apply], preserves morphological detail, the object then was saved as .cly file.

The "Object List" was displayed on the left top of the window by pressing the **o** key on the keyboard (Object List is also hidden by pressing **o** key again). The Object List shows the icons of the object and created planes.

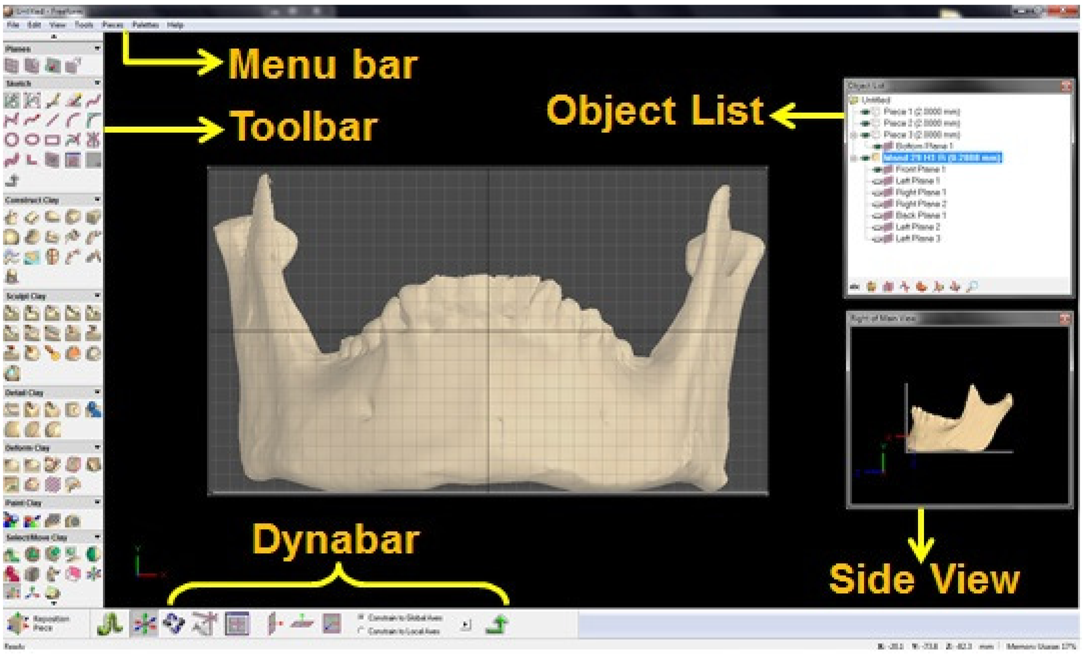
On the "Object List", the planes can be hidden by clicking the eye icon next to the name of each plane "open eye", meant the piece is visible, whereas, "closed eye", meant it is hidden.

The pieces in the Object List can be renamed to be more descriptive.

The piece icon was clicked (or right-click with the mouse on the current name of the piece) (Display the Object List by pressing **o** key if it is not already open) to display the piece's submenu, and then Rename from the menu was selected, the new name was written, and then click away of icon to finish the process.

The Side View window was also displayed by selecting Show Side View from the View menu, and then From Right of Main View was selected. It can be also displayed by pressing the **F6** key function on keyboard (Figure 25).

Figure 25: FreeForm™ Application Window



When unwanted artefacts were visible in the object scan, there were "cleaned" using the "Carve with Ball" and "Cut" tools, which cleaned the scan while avoiding cutting away necessary details.

The "Clay Hardness" slider in the "Sculpt Dynabar" was used to adjust the hardness of the digital clay, the hardness of the clay was changed using a slider control by clicking the cursor on the "clay hardness slider" and dragging it left for "harder" and right for "softer" clay.

Residual roughness was "cleaned" with the "smooth" tool on the sculpt clay on the toolbar. The smooth level slider was used to adjust the level of smoothing by clicking the cursor on the smooth level slider and dragging it left for "low" smoothing, and right for “fine” smoothing. The “low level” was chosen to smooth sharp edges only to avoid deleting bone or altering morphology.

For this the size of the FreeForm tools can be changed by clicking on the arrows in “spine box” next to Tool Size box or by typing a number in the Tool Size box and pressing the Enter key.

The size of the “Carve with Ball” and “Smooth” tools spheres can be changed also, by pressing the plus (+) key to increase and the minus (-) key to decrease. Acquired data was saved as a .cly file.

At this stage, the object was in the middle of the FreeForm application and ready for scanning.

After that, the object was moved using a combination of the PHANTOM desktop and keyboard keys.

The object also was moved using the mouse as follows. To rotate the object, the left mouse button was held down while moving the mouse.

To zoom the object and its plains, **h** key can be used instead of **g** key to move the object in and out, up and down, and left and right without rotation. This prevents accidently changing the orientation of the object during movement to zoom.

Eventually, both the size and the direction of the object were chosen.

After that, the **F2** function key was pressed to return the object to the centre of the FreeForm window, facing the way it did originally.

The **F3** and **F4** function keys on keyboard were used to move the object to show right and left views respectively.

The arrow keys on the keyboard were used to move the object quickly, precisely and easily a specific number of degrees, in any direction. Each press of the arrow key moved the object 15 degrees in one direction.

Using the function or arrow keys enabled the object to be moved without change of orientation.

Next, all points that represent the anatomical landmarks related to the region of supraorbital (Table 14), infraorbital (Table 15), mental (Table 16) and mandibular (Table 17) foramina that were used for the measurements of all distances related to the supraorbital (Table 10), infraorbital (Table 11), mental (Table 12) and mandibular (Table 13) foramina, were marked up using "Paint" tool.

The Paint Dynabar was displayed and the red colour was selected by clicking on a well on the colour palette.

The Blending Level Slider was used to adjust the level of paint blend (Light blend to the left side of the slider, heavy to the right).

The size of the "Paint" tool was adjusted to one that was appropriate for the landmarks, using the Diameter box in the Dynabar or the plus (+) & minus (-) keys on the keyboard to make the ball larger or smaller.

The landmarks were painted by the paint tool's handle by lightly applying pressure while holding down the PHANTOM button, and once the point was painted, the PHANTOM button was released. By using this process, all the anatomical landmarks on the object were marked up in red.

In FreeForm Modelling Plus™ there was an option to create a new plane. A new plane was displayed on the FreeForm application.

The plane was divided into small squares. The size of these squares could be increased or decreased.

The "Orient Flat to View" button was selected and the plane jumped to the front and centre of the application window.

The plane flattened in front of the object in a frontal view and perpendicular on the horizontal planes.

The Touch button in the Edit Plane Dynabar was selected; consequently, the plane was moved close until it was in contact with the object.

The FreeForm plane also could be moved and manipulated easily in any direction and to any location demanded, using the PHANTOM device.

In the Edit Plane Dynabar, Precise Movement (Shift) button could be selected or the shift key held down, while moving the tool to move and control the plane more slowly and precisely.

The plane was activated from the Object List (using the mouse to right click opposite the icon of the plane piece then the activate or edit option was selected on the submenu) or using the PHANTOM tool to activate the plane from the Object List or touch the plane with the PHANTOM cursor, when the stylus button was clicked to select the plane.

The PHANTOM device provides many ways to move the plane manually to accommodate following requirements:

(a) To resize the plane to fit the size of the object. The cursor was moved to touch and drag a corner of the plane, when it becomes a right-angled double-headed arrow with one arrowhead pointing up and the other pointing to the right/left. Pressing the stylus button on the PHANTOM tool, resize the plane to the desired length.

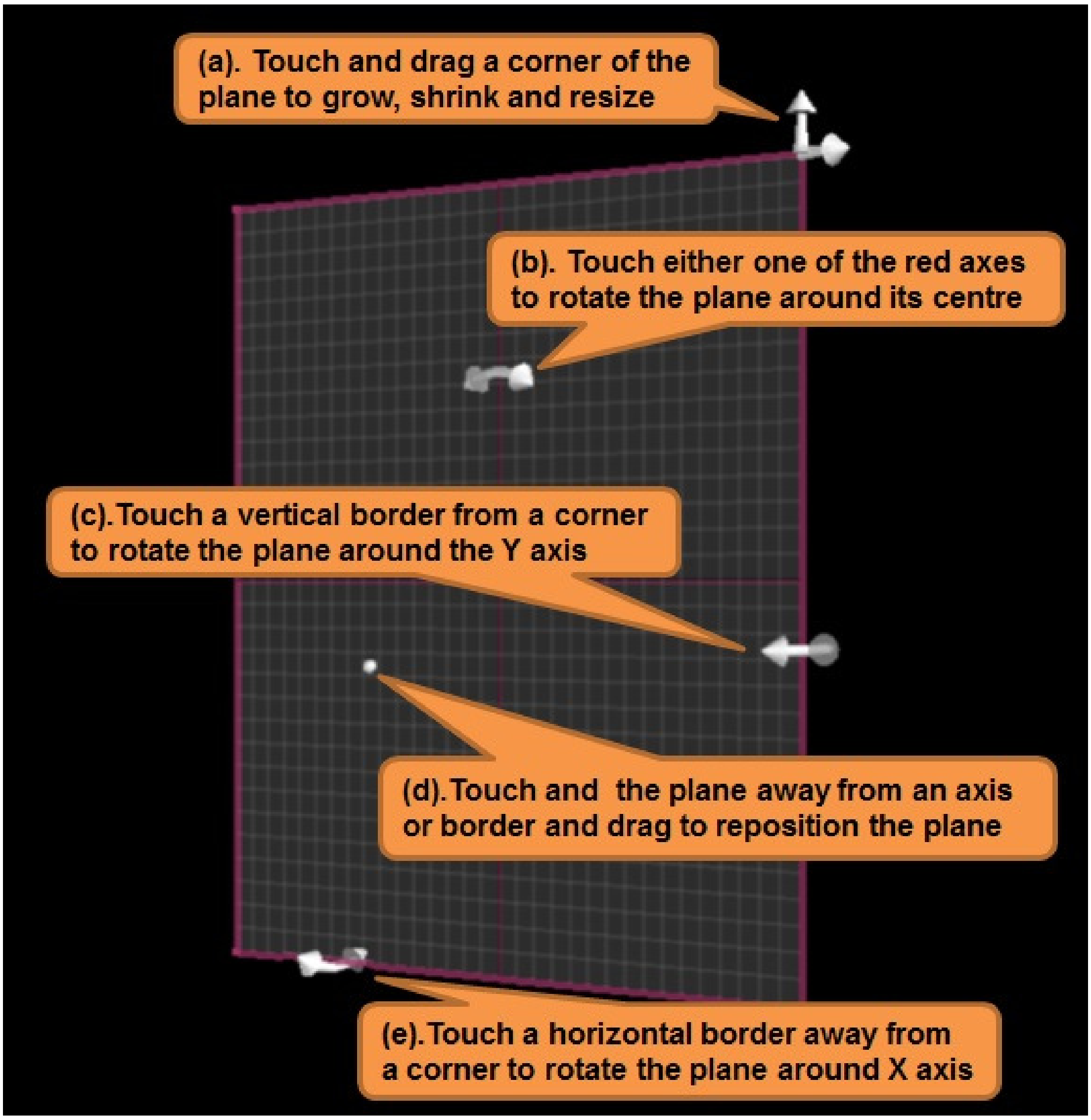
(b) To rotate the plane around its centre. The cursor was moved to touch either one of the red axes.

(c) To rotate the plane around the Y axis. To do this the cursor was move to touch a vertical border away from a corner.

(d) To reposition the plane. In this circumstance, the cursor was moved to touch the plane away from an axis or border, and then the plane was dragged to move it, without changing its orientation.

(e) To rotate the plane around the X axis. The cursor was moved to touch the horizontal border away from a corner (Figure 26).

Figure 26: Plane Movement in FreeForm™



Each cranium was placed in the horizontal position at which the plane passes through its Frankfurt plane, which is defined as "an imaginary horizontal plane passing through right and left porions and left orbitale".

A new plane was created and positioned in the flat position enabling the plane to move only without rotation.

Using the "Through Origin" button on the "Edit Plane Dynabar", the plane was moved to be in the centre of the cranium.

Using the haptic device, the plane was moved until it was positioned at the Frankfurt plane of the cranium.

On the Object List, the plane piece was moved above the object piece by the following.

1. The PHANTOM stylus button was clicked at the plane icon and the cursor was dragged until the "plane piece" was positioned above the "object piece".

2. Left mouse was clicked at the "plane icon" and dragged to position it above the object piece.

The object piece was activated from the Object List as following:

1. Right mouse was clicked at the icon of the object piece then activate or edit option was selected on the submenu.

2. When the PHANTOM cursor was on the object icon, the stylus button was clicked to select the object.

Subsequently, the object was moved by the PHANTOM Desktop Haptic Device without moving the plane.

The "Precise Movement" (Shift) button was selected enabling the tool moves more slowly and precisely to mount the object in the Frankfurt Horizontal Plane.

In the PHANTOM desktop software, variable camera zoom was controlled with the **h** key or mouse as described on page 121, while the **F3** and **F4** function keys were used to move the object to show the right and left views respectively, without change of the orientation of the object to make sure that the horizontal plane was positioned exactly on the right (Figure 27) and left (Figure 28) porions and left orbitale (Figure 29) of the cranium (Frankfurt plane).

Figure 27: Right View of Cranium Scan in FreeForm™ with a Plane at the Right Porion (Frankfurt Plane)

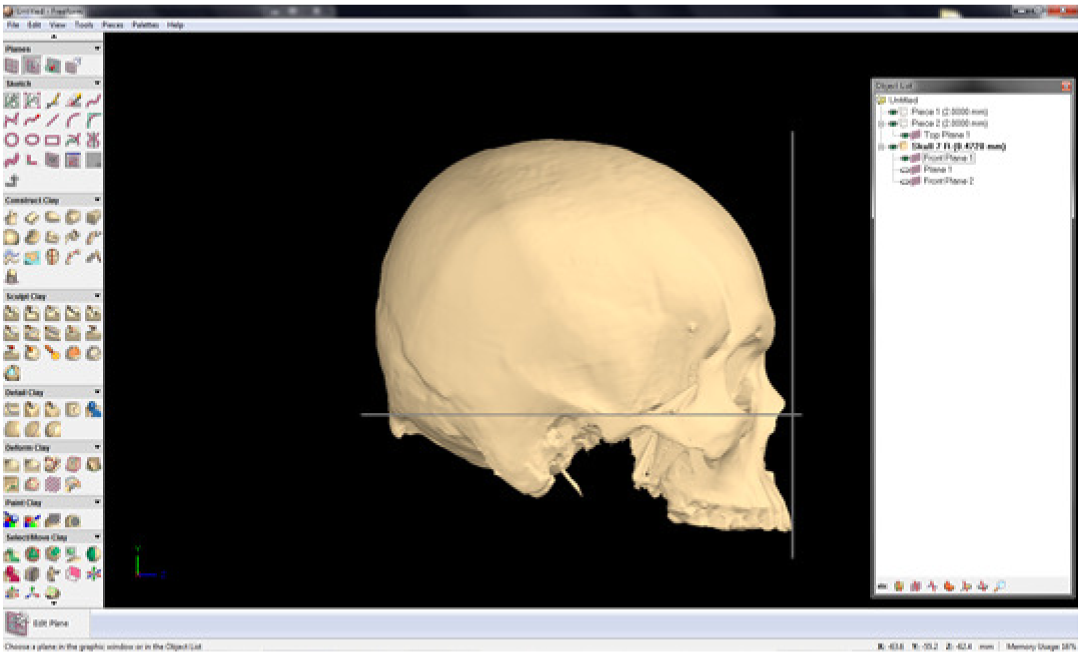


Figure 28: Left View of Cranium Scan in FreeForm™ with a Plane at the Left Porion (Frankfurt Plane)

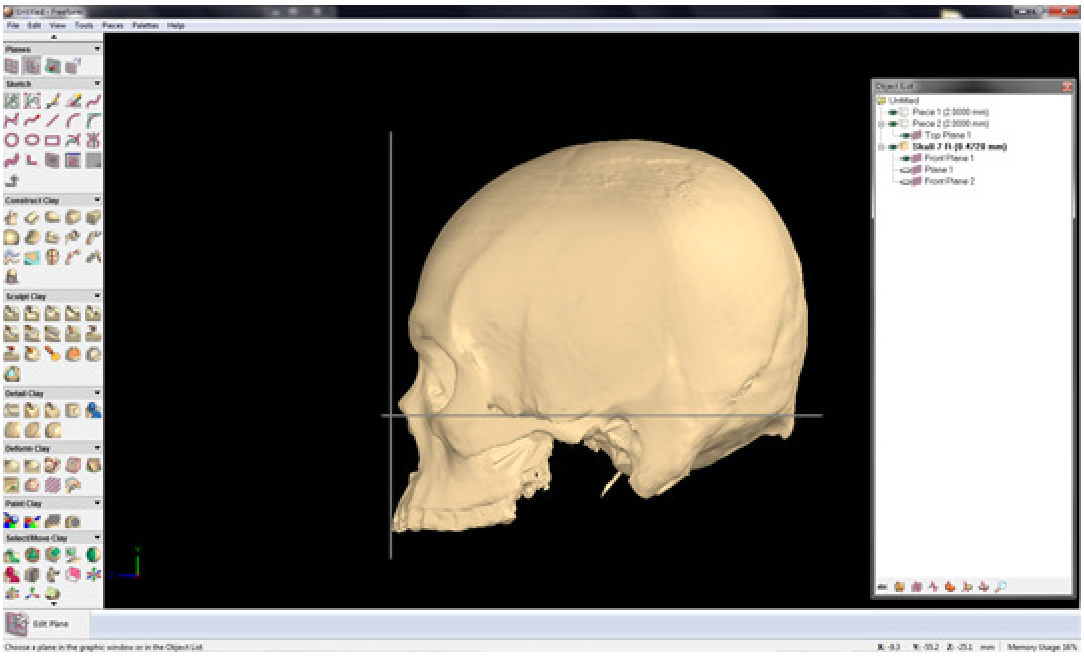
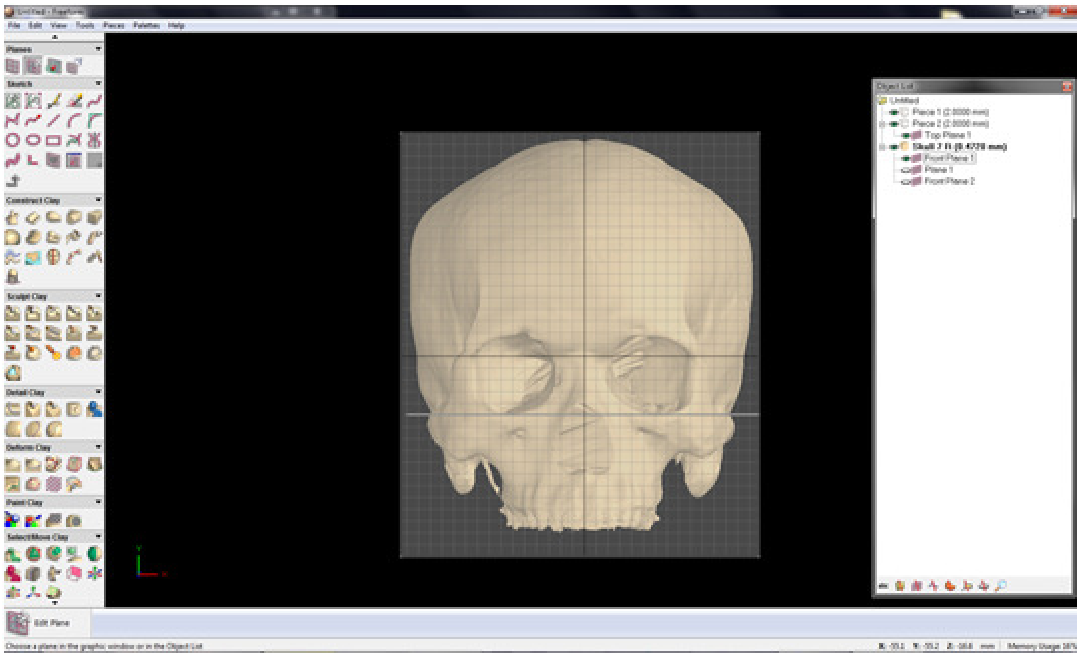


Figure 29: Frontal View of Cranium Scan in FreeForm™ with a Plane at the Left Orbitale (Frankfurt Plane) and a Plane in Front of the Cranium



Another new plane was created as described on page 122. The "Orient Through Three Points" piece was selected enabling the plane to be drawn through three anatomical landmarks (Nasion, anterior nasal spine and external occipital protuberance/ external occipital crest).

The cranium was moved precisely using arrow keys to show the frontal (Figure 30), basal (Figure 31), posterior basal (Figure 32) and top (Figure 33) views to make sure that the plane passed through the midline landmarks.

Figure 30: Frontal View of Cranium Scan in FreeForm™ with a Plane at the Midline (Nasion & Anterior Nasal Spine)

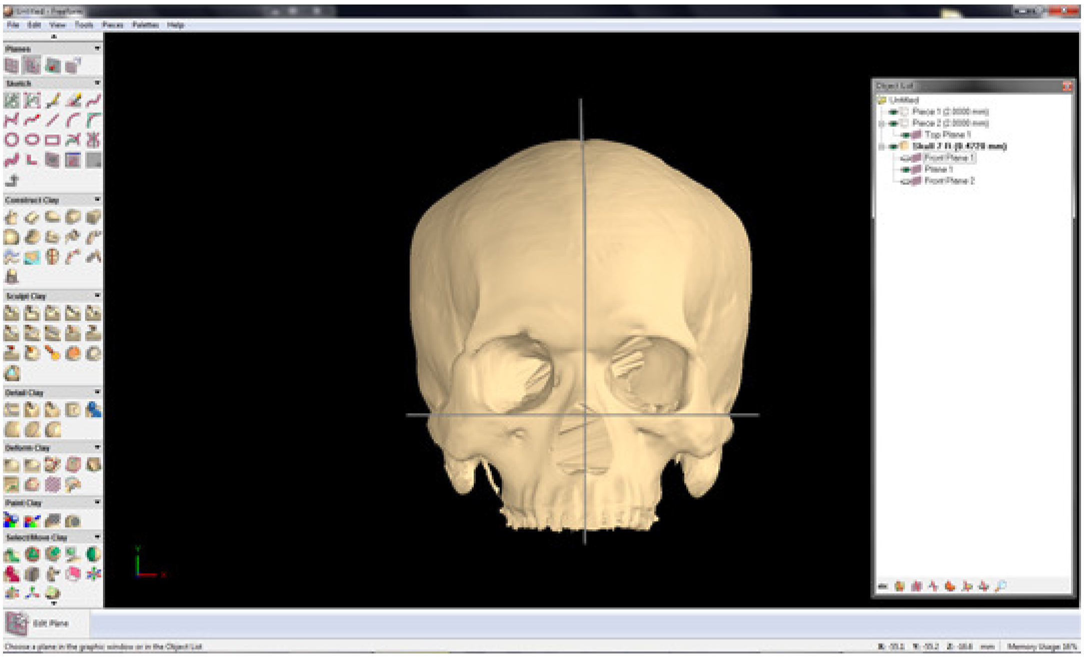


Figure 31: Basal View of Cranium Scan in FreeForm™ with a Plane at the Midline (External Occipital protuberance)

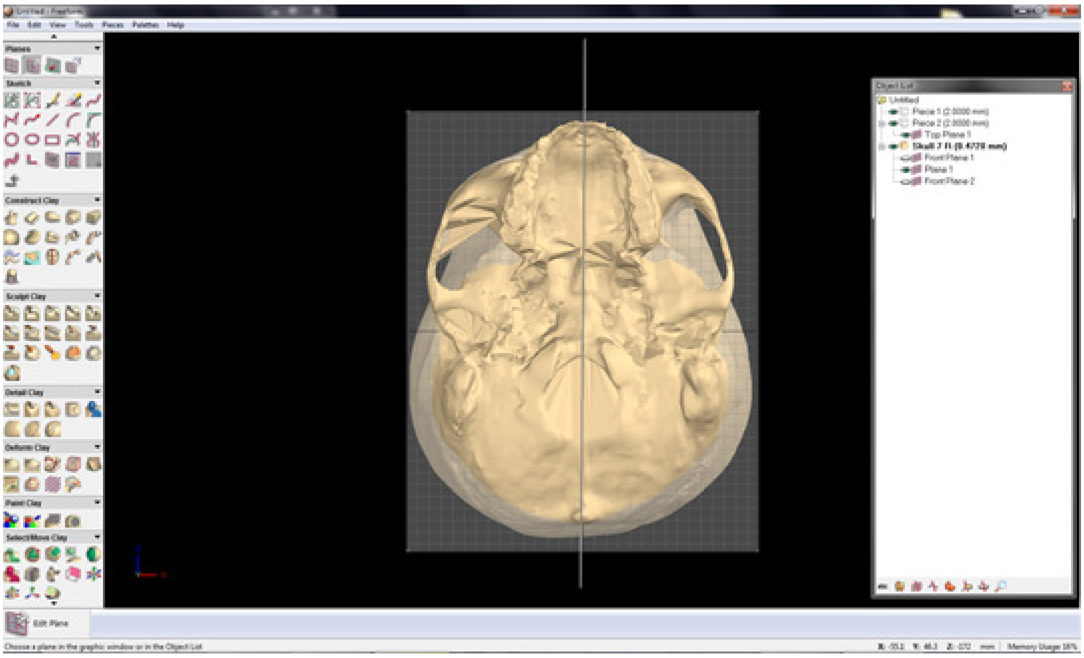


Figure 32: Posterior Basal View of Cranium Scan in FreeForm™ with a Plane at the Midline

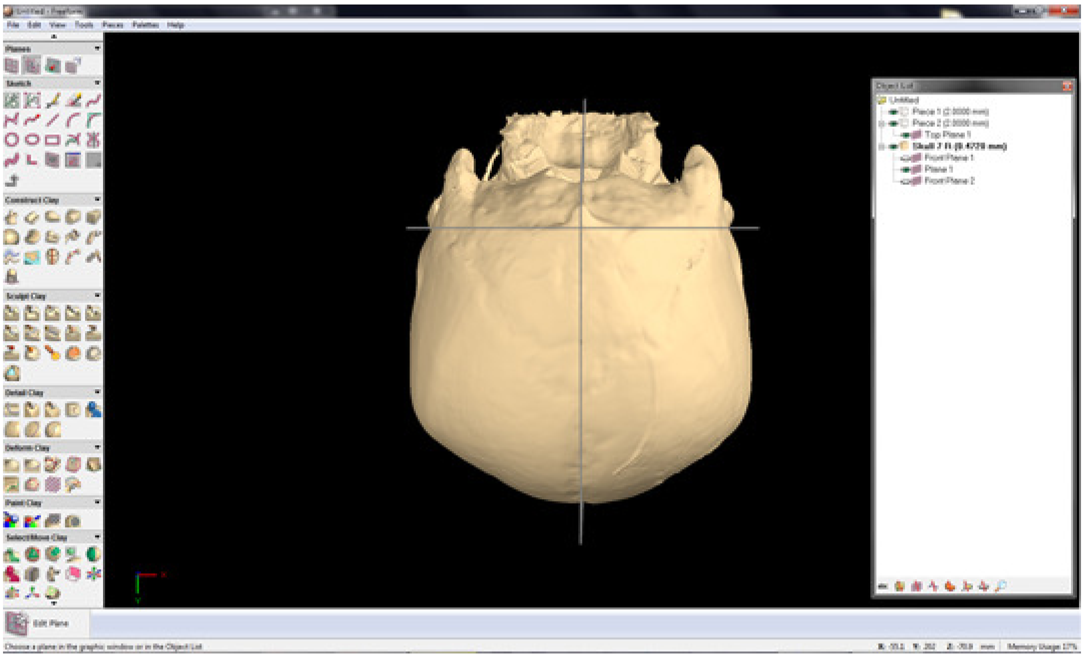
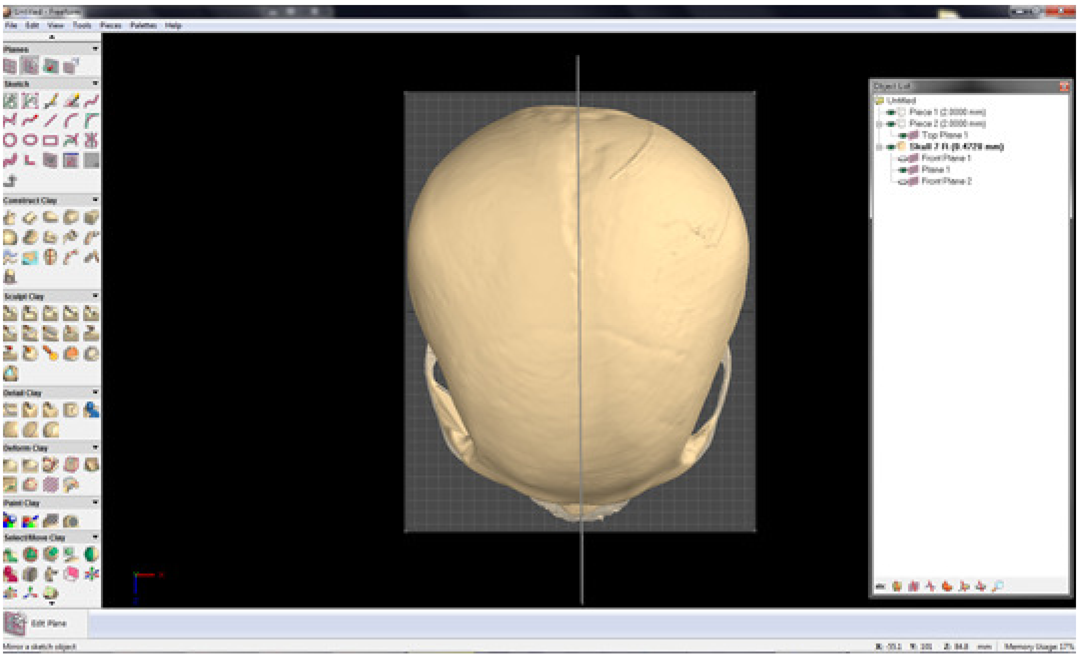


Figure 33: Top View of Cranium Scan in FreeForm™ with a Plane at the Midline



A new plane was created; “Orient Flat to View” button in the Edit Plane Dynabar was selected then the plane jumps to the front and centre of the application window, in front of the Cranium in a frontal view and perpendicular on the planes that were represented the Frankfurt plane and the midline of the Cranium.

The Touch button in the Edit Plane Dynabar was selected; hence the plane was moved to make contact with the cranium (Figure 29).

Points relating to the supraorbital and infraorbital foramina (Table 14 & 15) were marked sequentially (Figure 17, p106), as were the distances (Table 10 & 11) between these points. All distances were electronically measured using the “Ruler” tool.

The “Ruler” tool was selected from the Tools menu or pressed **R** key on the keyboard.

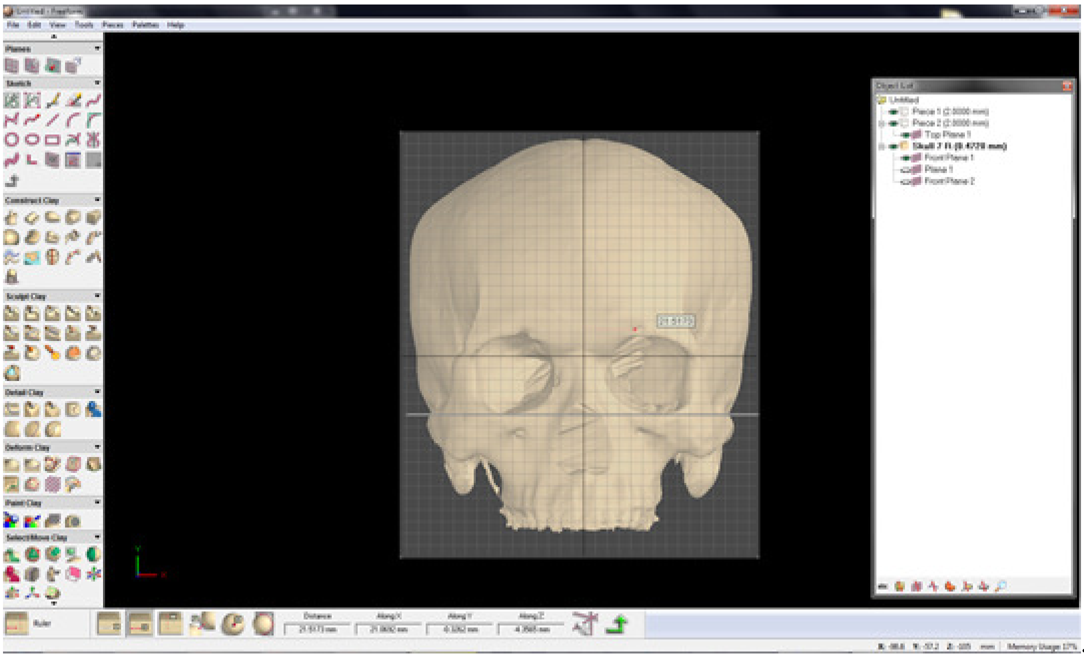
The Ruler option was clicked in Dynabar and the persistent ruler was displayed.

The PHANTOM device was used to place the end of the ruler on specific anatomical landmarks by clicking once and at the same time holding the stylus button.

The other end of the Ruler was positioned on another point which together forming a distance related to one of the four foramina and click the stylus button again, then slowly the tool pulled away from the object surface.

Eventually the measurement was displayed on the screen (Figure 34), and recorded. [All measurements in mm. corrected to two dismal places]

Figure 34: Cranium Scan in FreeForm™ with Ruler Measurement of D1E



Each mandible was placed on the horizontal basal plane, this time in the standard basal position, defined as "when contact is made at three or more points when vertical pressure is applied to the second left molar tooth" (Figure 35).

A new plane was created and repositioned horizontally.

The mandible was activated enabling the PHANTOM Desktop Haptic Device to move the mandible on the horizontal plane without moving the plane, as described on page 125, until the mandible stabilised and the standard horizontal position (Morant's position) of the mandible was achieved (Figure 35).

The mandible was zoomed as described on page 121 to make sure that the mandible did not penetrate through the horizontal plane (Figure 36).

Consequently, the mandible piece deactivated to stabilize its position in relation to horizontal basal plane.

Figure 35: Mandible Scan in FreeForm™ in Morant's Position

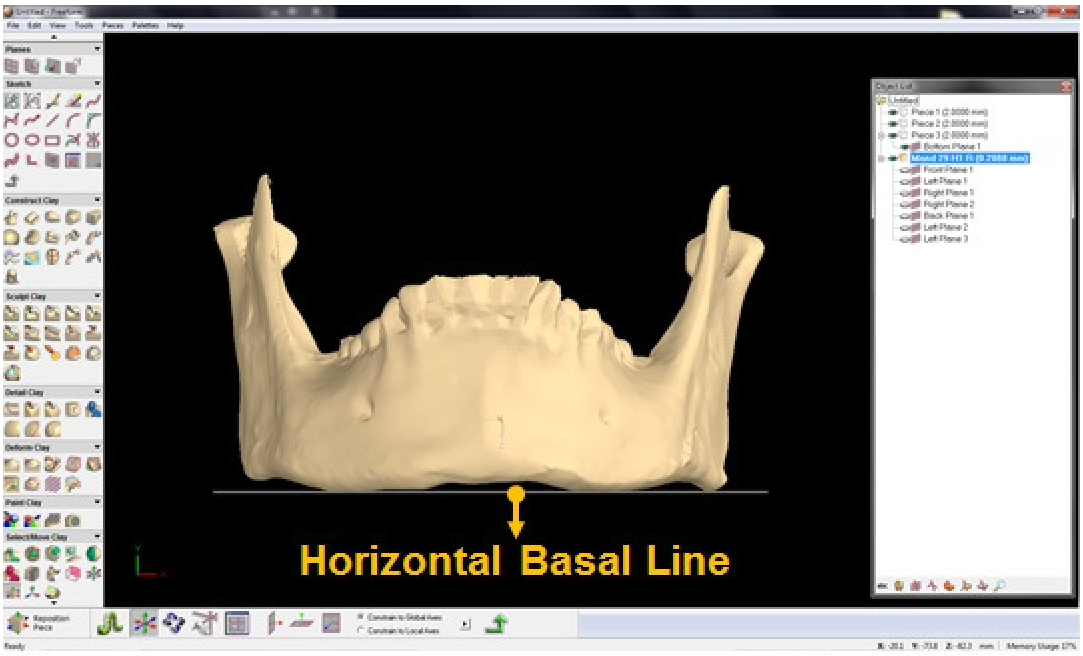
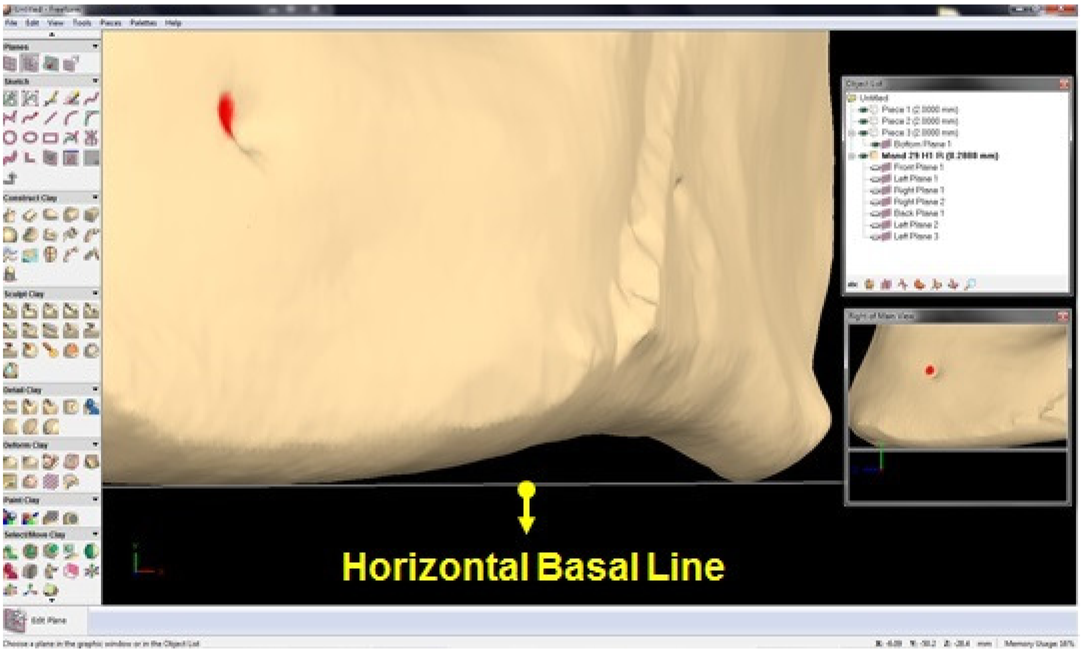


Figure 36: Mandible Scan in FreeForm™ in Morant's Position (Zoom)



The **F2** function key on keyboard was used to reposition the mandible with the horizontal to the same position and orientation.

A new plane was created in front of the mandible and the **F3** and **F4** function keys was pressed to move the mandible to show the right and left views and create a new plane for each view perpendicular to the horizontal plane. Consequently, all three planes were being flat and in contact with the mandible by using Touch button (Figure 37 & Figure 38).

Figure 37: Mandible Scan in FreeForm™ in Frontal View with Plane on Midline

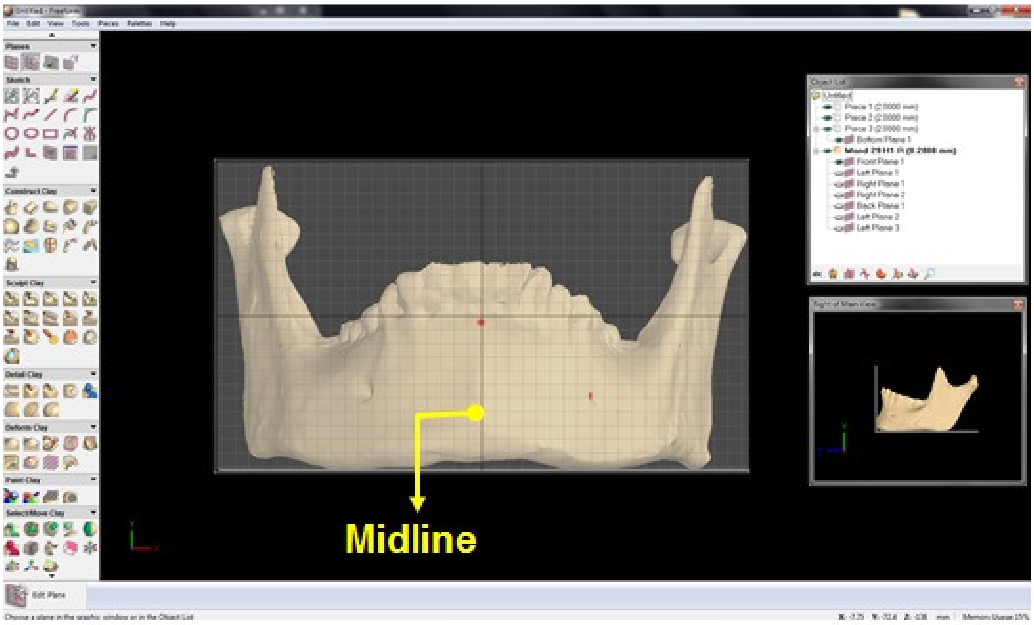
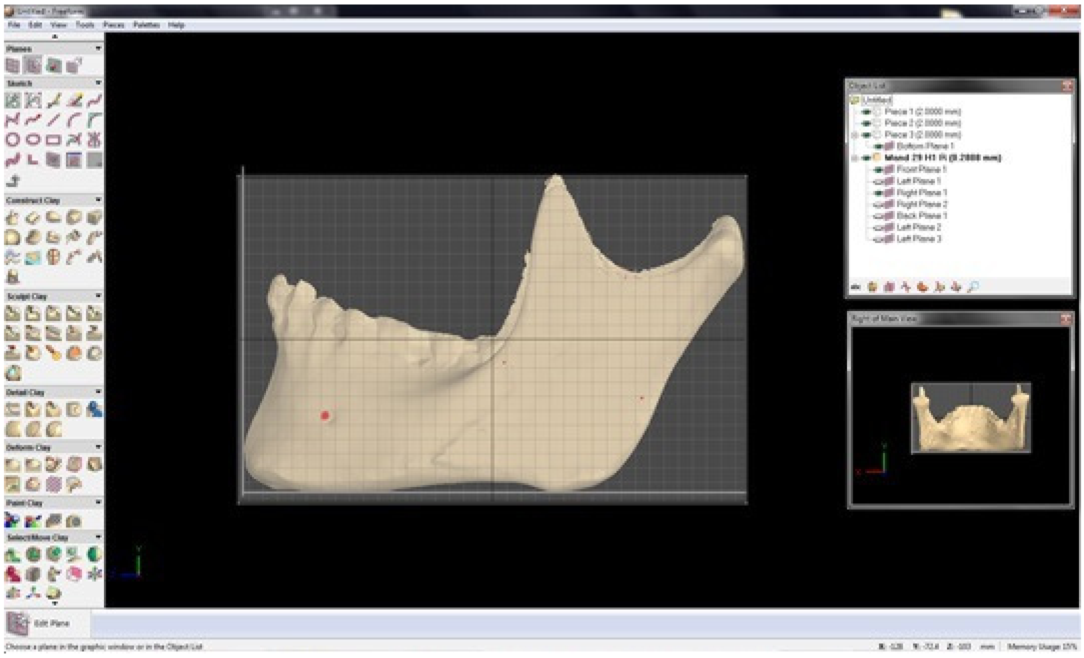


Figure 38: Mandible Scan in FreeForm™ in Left View with Plane



As with crania, points relating to the mental foramen were marked sequentially. The distances measured with the “Ruler” tool were taken as described on page 130, arrow keys were used to move the mandible slowly and precisely 15 degrees at a time.

The measurements were recorded in a table created particularly for distances D3A, D3B and D3C on both sides (See definitions of distances in Table 12, p 103).

The mandible was moved using arrow keys enabling me to notice the mandibular foramen on the internal surface of the ramus.

A new plane was created, flattened, repositioned and then it was made in contact the mandibular surface as described previously on page 122 and in Figure 39.

The distances, D4A, D4B, and D4C were measured and recorded in tables created particularly for thesis distances, then this plane was hidden.

Another new plane was created, flattened and repositioned.

The plane was rotated around its centre until the horizontal central axes was positioned to represent the occlusal line of the ipsilateral lower molars.

The plane was moved to be close and in contact with the mandibular surface as described previously on page 122 and in Figure 40.

The distances, D4D, D4E and D4G were measured and recorded in tables created particularly for these distances (See definitions of distances in Table 13, p 103).

The plane was dragged and repositioned to make the horizontal central line of the plane which represent the occlusal line was being shown on the lateral surface of the ramus to measure the distance D4H.

The "Ruler" tool as described on page 130 was used to take the measurements. [All measurements in mm. corrected to two dismal places]

The result was recorded in tables (see appendix) created particularly for this distance.

Figure 39: Mandible Scan in FreeForm™ in Left View of Ramus with Flat Plane

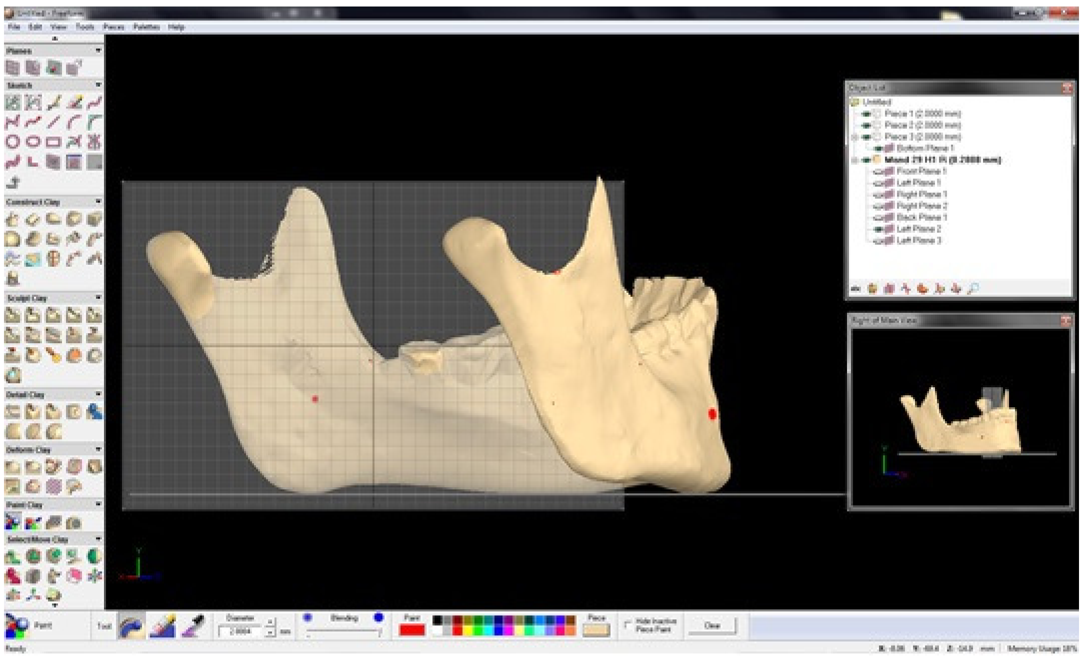
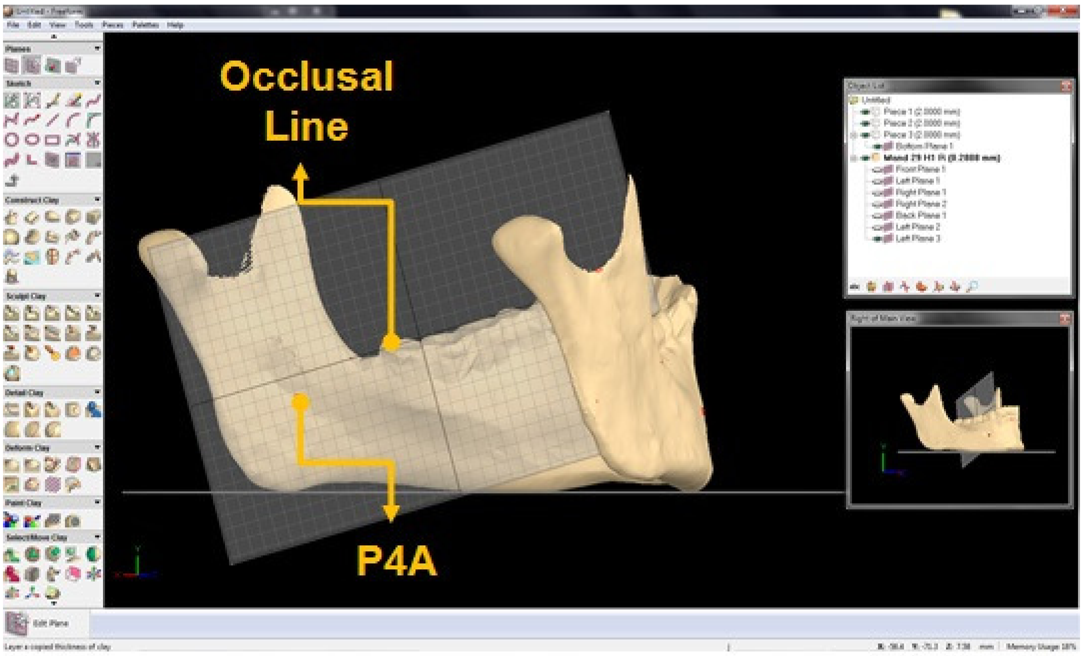


Figure 40: Mandible Scan in FreeForm™ in Left View of Ramus with Plane on the Occlusal Line



7.3.2.3 Observer reliability

Intra observer reliability

Aim: To evaluate how reliable measurements of the distances related to the four foramina were at different time periods, the Bland-Altman Plot analysis was undertaken.

Method: Ten crania and mandibles from the anatomy collection were selected by a second person and laid out. Measurements were taken for the four foramina at two different time periods.

Results: The full data and analysis are listed in appendix as this stretches to over 14 pages. Overall the strength of agreement was considered to be "very good".

Overall the strength of agreement was considered to be "very good".

Inter Observer Reliability

Aim: To evaluate the reproducibility of measurements between observers, of the distances related to the four foramina.

Method: Three skulls and mandibles were chosen independently of the observers. Measurements were undertaken by the author and two other observers and the three sets of measurements were then compared. The results were analysed using Intraclass Correlation (ICC), using IBM SPSS statistics x64, IBM SPSS statistics version 19.

The values are interpreted between 0 and 1 based on the guidelines from Landis & Koch (1977) (Table 19)

Table 19: Interpretation of ICC, based on Landis & Koch (1977)

Value	Strength of agreement
< 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very good

Results: The full data and analysis are listed in appendix. Overall there was a good to very good agreement between the three observers, and a few was moderate, with the exceptions of four data which depend on the interpretation of the position of the occlusal line.

7.3.3 Statistical Analysis

The data analysis was performed as follows:

1. A Bland-Altman plot approach was performed using GraphPad Prism (version 6.01 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) and was used to analyse the following:

- Validation of the Miles method using skulls of known age (p 85).
- Comparisons between electronic digital calliper and 3D laser scanning measurements of ipsilateral distances related to four foramina in each of the four populations (p 199).

2. Weighted Kappa, quantifying inter-rater agreements were calculated using GraphPad QuickCalcs (Web site: http://www.graphpad.com/quickcalcs/kappa1/cfm) and was used to analyse the following:

- Intra-observer scoring of occlusal tooth wears patterns (p 79).
- Inter-observer scoring of occlusal tooth wears patterns (p 82).
- Validation of the Brothwell method using skulls of known age (p 93).

3. Paired t test was performed using GraphPad Prism (version 6.01 for Windows GraphPad Software, La Jolla California USA, www.graphpad.com) and was used to analyse the following:

- Intra-population comparisons between right and left sides in each population group using the electronic calliper method (p 140).
- Intra-population comparisons between right and left sides in each population group, using the laser scanning method (p 179).

4. Unpaired t test was performed using GraphPad Prism (version 6.01 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) and was used to analyse the following:

- Inter-population comparisons between ipsilateral distances in four population groups using the electronic calliper method (p 147).
- Inter-population comparisons between ipsilateral distances in four population groups using the laser scanning method (p 186).

5. One-way ANOVA was performed using GraphPad InStat (version 3.06 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) and was used to analyse the following:

- Intra-population comparisons of foraminal positions with respect to age in each of the four groups (p 161).

6. Compute Pearson Correlation Coefficient was performed using GraphPad Prism (version 6.01 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) and was used to analyse:

- The correlation between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible on both sides in each population (p160).

7. Intraclass Correlation (ICC) was performing using IBM SPSS statistics x64, IBM SPSS statistics version 19 and was used to analyse:

- The inter observer reliability of the 3D laser scanning method (p 137).

Chapter 8
Results of Main Study

A list of the definitions of all the distances is presented on page 103.

8.1 Electronic Digital Calliper Method

8.1.1 Intra-Population Comparisons between the Right and Left Sides in Each Population Group

Summary: There was no significant difference between the right and left sides in each of four population groups in regard to the all distances related to the four foramina except that there were statistically significant differences between the right and left sides in the Hylam and Indian populations in regard to the distance from the supraorbital foramen to the temporal crest, in the Hylam population in regard to the distance from the mandibular foramen to the posterior border of the ramus at the same level and in the Indian population in regard to the distance from the mandibular foramen to the internal oblique ridge at the occlusal line.

8.1.1.1 Distances Related to the Supraorbital Foramen

In the following three tables the distances related to supraorbital region on the right and left sides of each population are compared.

a. Supraorbital Foramen to Midline: Distance D1B

Table 20: Distance D1B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	22.77(±3.69)[1]	21.89(±3.06)[1]	-1.985 to 0.4955	**0.2272**
Hylam	23.73(±3.22)[2]	24.03(±3.88)[2]	-0.8445 to 1.242	**0.6991**
Indian	23.08(±3.18)[3]	22.51(±3.44)[3]	-2.013 to 0.8721	**0.4241**
British	22.33(±3.16)[4]	21.78(±3.54)[4]	-1.473 to 0.3985	**0.2491**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; $p > 0.05$.

b. Supraorbital Foramen to Temporal Crest: Distance D1C

Table 21: Distance D1C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	24.11(±3.34)[1]	23.59(±2.49)[1]	-1.800 to 0.1644	**0.0986**
Hylam	23.72(±3.39)	22.72(±3.93)	-1.803 to -0.2048	**0.0157**
Indian	26.30(±2.48)	25.42(±3.38)	-1.649 to -0.1085	**0.0269**
British	27.26(±.3.31)[2]	26.66(±3.40)[2]	-1.323 to 0.03206	**0.0610**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; $p > 0.05$.

c. Supraorbital Foramen to Supraorbital Rim: Distance D1D

Table 22: Distance D1D

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	2.37(±1.89)[1]	2.52(±1.16)[1]	-2.179 to 1.824	**0.8399**
Hylam	2.66(±1.58)[2]	2.64(±2.17)[2]	-1.203 to 1.831	**0.6506**
Indian	1.87(±0.85)[3]	1.91(±0.99)[3]	-1.259 to 0.6915	**0.5136**
British	2.48(±0.86)[4]	2.19(±0.87)[4]	-1.638 to 1.902	**0.8461**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; $p > 0.05$.

8.1.1.2 Distances Related to Infraorbital Foramen

The following six tables compare the distances related to infraorbital region on the right and left sides of each population.

a. Infraorbital Foramen to Midline at the Level of the Supraorbital Foramen: Distance D2B

Table 23: Distance D2B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	25.66(±2.10)1	25.22(±2.43)[1]	-1.009 to 0.1194	**0.1177**
Hylam	26.08(±2.07)[2]	26.46(±2.29)[2]	-0.3786 to 1.130	**0.3168**
Indian	25.17(±2.11)[3]	25.39(±1.68)[3]	-0.6225 to 1.066	**0.5953**
British	24.20(±2.45)[4]	24.85(±2.41)[4]	-0.05056 to 1.355	**0.0677**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; $p > 0.05$.

b. Infraorbital Foramen to Anterior Nasal Spine: Distance D2C

Table 24: Distance D2C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	28.91(±2.48)1	28.20(±3.23)[1]	-1.657 to 0.2210	**0.1287**
Hylam	30.63(±2.63)[2]	30.01(±2.88)[2]	-1.326 to 0.08848	**0.0840**
Indian	29.33(±2.21)[3]	28.82(±2.06)[3]	-0.9841 to 0.03725	**0.0679**
British	30.49(±3.24)[4]	29.91(±3.09)[4]	-1.242 to 0.08469	**0.0849**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; $p > 0.05$.

c. Infraorbital Foramen to Zygomatico-Maxillary Suture: Distance D2E

Table 25: Distance D2E

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	8.70(±1.68)[1]	8.44(±1.71)[1]	-0.6573 to 0.1340	**0.1866**
Hylam	9.29(±1.86)[2]	8.94(±1.80)[2]	-0.8919 to 0.1913	**0.1962**
Indian	7.23(±1.87)[3]	7.54(±2.08)[3]	-0.1592 to 0.7826	**0.1863**
British	7.96(±2.04)[4]	8.20(±1.92)[4]	-0.1094 to 0.5774	**0.1740**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

d. Infraorbital Foramen to Infraorbital Rim: Distance D2F

Table 26: Distance D2F

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	8.35(±1.87)[1]	8.17(±1.36)[1]	-0.5797 to 0.2224	**0.3697**
Hylam	8.49(±1.57)[2]	8.47(±1.52)[2]	-0.4954 to 0.4720	**0.9610**
Indian	6.89(±1.95)[3]	6.84(±1.97)[3]	-0.4491 to 0.3458	**0.7922**
British	7.54(±1.72)[4]	7.85(±2.13)[4]	-0.1433 to 0.7600	**0.1732**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

e. Infraorbital to Supraorbital Foramen (Vertically): Distance D2G

Table 27: Distance D2G

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	44.15(±2.99)[1]	43.86(±2.81)[1]	-0.7520 to 0.1853	**0.2262**
Hylam	43.96(±2.94)[2]	44.28(±3.11)[2]	-0.3529 to 0.9796	**0.3441**
Indian	40.43(±3.36)[3]	40.40(±3.21)[3]	-0.6371 to 0.5698	**0.9099**
British	43.28(±3.29)[4]	43.29(±3.25)[4]	-0.4354 to 0.4554	**0.9637**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

f. Infraorbital to Supraorbital Foramina (Horizontally): Distance D2H

Table 28: Distance D2H

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	-2.23(±4.04)[1]	-3.44(±3.27)[1]	-2.862 to 0.4418	**0.1447**
Hylam	-2.04(±3.73)[2]	-3.19(±3.86)[2]	-2.653 to 0.1540	**0.0789**
Indian	-2.22(±3.13)[3]	-3.63(±3.69)[3]	-3.069 to 0.2530	**0.0934**
British	-2.26(±3.99)[4]	-3.90(±4.50)[4]	-3.061 to 0.02632	**0.0538**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.1.3 Distances Related to Mental Foramen

In the following two tables the distances related to mental foramen region on the right and left sides of each population group are compared.

a. Mental Foramen to Symphysis Menti: Distance D3A

Table 29: Distance D3A

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	27.66 (± 1.61)[1]	27.49 (± 1.59)[1]	-0.6342 to 0.2949	**0.4611**
Hylam	28.20 (± 2)[2]	28.14 (± 1.93)[2]	-0.3960 to 0.2807	**0.7299**
Indian	27.05 (± 1.62)[3]	27.00 (± 1.84)[3]	-0.6765 to 0.5838	**0.8815**
British	26.54 (± 2.55)[4]	26.92 (± 2.49)[4]	-0.1392 to 0.9006	**0.1451**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Mental Foramen to Posterior Border of the Ramus: Distance D3B

Table 30: Distance D3B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	69.27 (± 4.21)[1]	69.74 (±3.85)[1]	-0.3603 to 1.292	**0.2583**
Hylam	72.00 (± 4.37)[2]	71.44 (±4.25)[2]	-1.290 to 0.1636	**0.1238**
Indian	68.78 (± 3.89)[3]	69.06 (±3.76)[3]	-0.4115 to 0.9621	**0.4189**
British	71.98 (± 5.04)[4]	72.74 (±5.40)[4]	-0.2381 to 1.762	**0.1300**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations ($P > 0.05$)

8.1.1.4 Distances Related to Mandibular Foramen

In the following eight tables the distances related to mandibular foramen region on the right and left sides of each population are compared.

a. Mandibular Foramen to Inferior Border of the Mandible: Distance D4A

Table 31: Distance D4A

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	25.23(±3.39)[1]	24.79(±3.55)[1]	-1.191 to 0.3039	**0.2347**
Hylam	24.87(±3.24)[2]	25.05(±3.81)[2]	-0.4495 to 0.8188	**0.5561**
Indian	22.84(±3.78)[3]	22.83(±4.00)[3]	-0.5810 to 0.5510	**0.9571**
British	23.20(±3.77)[4]	23.44(±3.66)[4]	-0.2427 to 0.7220	**0.3179**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Mandibular Foramen to the Condylar Notch: Distance D4B

Table 32: Distance D4B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	24.32(±3.21)[1]	24.05(±3.04)[1]	-1.058 to 0.5022	**0.4720**
Hylam	22.90(±3.54)[2]	22.81(±3.54)[2]	-0.6861 to 0.5081	**0.7627**
Indian	22.96(±3.81)[3]	22.67(±3.22)[3]	-0.9823 to 0.3989	**0.3948**
British	25.44(±3.34)[4]	25.07(±2.90)[4]	-0.9971 to 0.2551	**0.2353**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

c. Mandibular Foramen to Posterior Border of the Ramus at the Same Level: Distance D4C

Table 33: Distance D4C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	17.39(±1.84)[1]	17.14(±1.53)[1]	-0.5977 to 0.09173	**0.1442**
Hylam	17.85(±2.36)	17.38(±2.05)	-0.9029 to -0.04247	**0.0324**
Indian	15.59(±2.01)[2]	15.86(±1.96)[2]	-0.1978 to 0.7371	**0.2477**
British	15.89(±2.09)[3]	15.73(±1.97)[3]	-0.6564 to 0.3451	**0.5299**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

d. Mandibular Foramen to Posterior Border of the Ramus at Occlusal Line: Distance D4D

Table 34: Distance D4D

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	18.54(±2.66)[1]	18.28(±2.28)[1]	-1.228 to 0.7061	**0.5852**
Hylam	18.40(±2.92)[2]	17.71(±2.76)[2]	-1.578 to 0.2025	**0.1249**
Indian	16.97(±3.00)[3]	16.73(±2.37)[3]	-0.9096 to 0.4456	**0.4893**
British	16.84(±2.72)[4]	16.51(±2.16)[4]	-1.150 to 0.5031	**0.4301**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

e. Mandibular Foramen to Internal Oblique Ridge at Occlusal Line: Distance D4E

Table 35: Distance D4E

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	14.70(±2.30)[1]	15.54(±2.96)[1]	0.3561 to 0.9561	**0.3574**
Hylam	14.87(±1.95)[2]	14.93(±2.07)[2]	-0.4907 to 0.6027	**0.8355**
Indian	13.48(±2.25)	12.99(±2.06)	-0.9298 to -0.05691	**0.0281**
British	15.11(±2.39)[3]	14.93(±1.75)[3]	-0.6959 to 0.3419	**0.4910**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

f. Mandibular Foramen to Occlusal Line: Distance D4F

Table 36: Distance D4F

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	-4.68(±4.24)[1]	-4.72(±5.06)[1]	-1.505 to 1.430	**0.9589**
Hylam	-4.14(±3.59)[2]	-3.45(±3.49)[2]	-0.6953 to 2.091	**0.3141**
Indian	-4.73(±3.30)[3]	-3.80(±3.17)[3]	-0.05264 to 1.905	**0.0628**
British	-4.23(±3.10)[4]	-3.80(±2.27)[4]	-0.5358 to 1.384	**0.3737**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

g. Internal Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Distance D4G

Table 37: Distance D4G

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	31.78(±2.86)[1]	32.09(±2.98)[1]	-0.1991 to 1.120	**0.1640**
Hylam	32.65(±2.78)[2]	32.19(±2.74)[2]	-1.115 to 0.2110	**0.1738**
Indian	29.45(±2.30)[3]	29.24(±2.71)[3]	-0.7366 to 0.3160	**0.4204**
British	30.71(±2.98)[4]	30.01(±4.35)[4]	-2.004 to 0.6104	**0.2845**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

h. External Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Distance D4H

Table 38: Distance D4H

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	35.61(±2.78)[1]	35.96(±2.93)[1]	-0.2814 to 0.9927	**0.2628**
Hylam	35.37(±2.73)[2]	36.04(±5.85)[2]	-1.277 to 2.623	**0.4857**
Indian	32.69(±2.64)[3]	32.84(±2.99)[3]	-0.5460 to 0.8466	**0.6621**
British	32.84(±2.97)[4]	32.98(±3.53)[4]	-0.6691 to 0.9631	**0.7153**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.2 Inter-Population Comparisons between the ipsilateral Distances in Four Population Groups

In the following tables ipsilateral distances between the Hokien-Hylam, Hokien-Indian, Hokien-British, Hylam-Indian, Hylam-British and Indian-British populations are compared.

Summary: Where ipsilateral comparisons were carried out between four populations, there were some statistically significant differences with regard to the all maxillofacial foramina but all these differences were not clinically relevant except the distances between the British and Hylam with regard to distances between right and left supraorbital foramina.

8.1.2.1 Distances Related to Supraorbital Foramen

Table 39: Inter-Population Comparisons of: (D1B R, D1B L & D1A)

(a) The distance from the supraorbital foramen to the midline: right side [D1B R].

(b) The distance from the supraorbital foramen to the midline: left side [D1B L].

(c) The distance between the right and the left supraorbital foramen [D1A].

	D1B R	D1B L	D1A
Hokien Mean(±SD)	22.77(±3.69)[1]	21.89(±3.06)	43.70(±5.87)[11]
Hylam Mean(±SD)	23.73(±3.22)[1]	24.03(±3.88)	46.90(±6.81)[11]
95% Confidence Interval	-0.8761 to 2.788	25.84 to 4.021	-0.2613 to 6.655
P value (Difference between Mean Hokien &Mean Hylam)	**0.3003**	**0.0266**	**0.0693**
Hokien Mean(±SD)	22.77(±3.69)[2]	21.89(±3.06)[7]	43.70(±5.87)[12]
Indian Mean(±SD)	23.08(±3.18)[2]	22.51(±3.44)[7]	44.38(±4.67)[12]
95% Confidence Interval	-1.547 to 2.171	-1.144 to 2.380	-2.209 to 3.562
P value (Difference between Mean Hokien &Mean Indian)	**0.7379**	**0.4848**	**0.6400**
Hokien Mean(±SD)	22.77(±3.69)[3]	21.89(±3.06)[8]	43.70(±5.87)[13]
British Mean(±SD)	22.33(±3.16)[3]	21.78(±3.54)[8]	41.54(±5.75)[13]
95% Confidence Interval	-2.278 to 1.394	-1.903 to 1.677	-5.307 to 0.9804
P value (Difference between Mean Hokien &Mean British)	**0.6315**	**0.8998**	**0.1733**
Hylam Mean(±SD)	23.73(±3.22)[4]	24.03(±3.88)[9]	46.90(±6.81)[14]
Indian Mean(±SD)	23.08(±3.18)[4]	22.51(±3.44)[9]	44.38(±4.67)[14]
95% Confidence Interval	-2.327 to 1.039	-3.472 to 0.4287	-5.631 to 0.5905
P value (Difference between Mean Hylam &Mean Indian)	**0.4464**	**0.1237**	**0.1102**
Hylam Mean(±SD)	23.73(±3.22)[5]	24.03(±3.88)	46.90(±6.81)
British Mean(±SD)	22.33(±3.16)[5]	21.78(±3.54)	41.54(±5.75)
95% Confidence Interval	-3.061 to 0.2654	-4.227 to -0.2788	-8.675 to -2.045
P value (Difference between Mean Hylam &Mean British)	**0.0979**	**0.0261**	**0.0020**
Indian Mean(±SD)	23.08(±3.18)[6]	22.51(±3.44)[10]	44.38(±4.67)
British Mean(±SD)	22.33(±3.16)[6]	21.78(±3.54)[10]	41.54(±5.75)
95% Confidence Interval	-2.436 to 0.9290	-2.601 to 1.139	-5.625 to -0.05483
P value (Difference between Mean Indian &Mean British)	**0.3734**	**0.4365**	**0.0458**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 40: Inter-Population Comparisons of: (D1C R, D1C L, D1D R & D1D L)

(a) The distance from the supraorbital foramen to the temporal crest: right side [D1C R].

(b) The distance from the supraorbital foramen to the temporal crest: left side [D1C L].

(c) The distance from the supraorbital foramen to the supraorbital rim:right side [D1D R]

(d) The distance from the supraorbital foramen to the supraorbital rim: left side [D1D L].

	D1C R	D1C L	D1D R	D1D L
Hokien Mean(±SD)	24.11(±3.34)[1]	23.69(±2.50)[3]	2.37(±1.89)[5]	2.52(±1.16)[11]
Hylam Mean(±SD)	23.72(±3.39)[1]	22.89(±3.97)[3]	2.66(±1.58)[5]	2.64(±2.17)[11]
95% Confidence Interval	-2.177 to 1.401	-2.556 to 0.9100	-1.106 to 1.700	-1.319 to 1.569
P value (Difference between Mean Hokien &Mean Hylam)	**0.6655**	**0.3321**	**0.6663**	**0.8596**
Hokien Mean(±SD)	24.11(±3.34)	23.69(±2.50)	2.37(±1.89)[6]	2.52(±1.16)[12]
Indian Mean(±SD)	26.30(±2.48)	25.42(±3.38)	1.87(±0.85)[6]	1.91(±0.99)[12]
95% Confidence Interval	0.5989 to 3.773	0.2168 to 3.437	-1.696 to 0.7022	-1.500 to 0.2813
P value (Difference between Mean Hokien &Mean Indian)	**0.0079**	**0.0269**	**0.4003**	**0.1704**
Hokien Mean(±SD)	24.11(±3.34)	23.69(±2.50)	2.37(±1.89)[7]	2.52(±1.16)[13]
British Mean(±SD)	27.26(±3.31)	26.66(±3.40)	2.48(±0.86)[7]	2.19(±0.87)[13]
95% Confidence Interval	1.370 to 4.933	1.397 to 4.590	-1.503 to 1.721	-1.404 to 0.7399
P value (Difference between Mean Hokien &Mean British)	**0.0008**	**0.0004**	**0.8882**	**0.5222**
Hylam Mean(±SD)	23.72(±3.39)	22.89(±3.97)	2.66(±1.58)[8]	2.64(±2.17)[14]
Indian Mean(±SD)	26.30(±2.48)	25.42(±3.38)	1.87(±0.85)[8]	1.91(±0.99)[14]
95% Confidence Interval	1.002 to 4.147	0.7453 to 4.644	-1.809 to 0.2219	-2.088 to 0.6196
P value (Difference between Mean Hylam &Mean Indian)	**0.0018**	**0.0076**	**0.1201**	**0.2746**
Hylam Mean(±SD)	23.72(±3.39)	22.89(±3.97)	2.66(±1.58)[9]	2.64(±2.17)[15]
British Mean(±SD)	27.26(±3.31)	26.66(±3.40)	2.48(±0.86)[9]	2.19(±0.87)[15]
95% Confidence Interval	1.793 to 5.286	1.979 to 5.886	-1.534 to 1.158	-2.258 to 1.344
P value (Difference between Mean Hylam &Mean British)	**0.0002**	**0.0002**	**0.7733**	**0.6013**
Indian Mean(±SD)	26.30(±2.48)[2]	25.42(±3.38)[4]	1.87(±0.85)[10]	1.91(±0.99)[16]
British Mean(±SD)	27.26(±3.31)[2]	26.66(±3.40)[4]	2.48(±0.86)[10]	2.19(±0.87)[16]
95% Confidence Interval	-0.5913 to 2.522	-0.5779 to 3.054	-0.2364 to 1.448	-0.6604 to 1.215
P value (Difference between Mean Indian &Mean British)	**0.2192**	**0.1774**	**0.1481**	**0.5424**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 41: Inter-Population Comparisons of: (D1E)

(a) The distance between the right and the left fronto-zygomatic sutures [D1E].

	D1E
Hokien Mean(±SD)	102.8(±3.54)[1]
Hylam Mean(±SD)	104.7(±3.69)[1]
95% Confidence Interval	-0.009631 to 3.728
P value (Difference between Mean Hokien &Mean Hylam)	**0.0512**
Hokien Mean(±SD)	102.8(±3.54)[2]
Indian Mean(±SD)	102.3(±3.58)[2]
95% Confidence Interval	-2.330 to 1.350
P value (Difference between Mean Hokien &Mean Indian)	**0.5962**
Hokien Mean(±SD)	102.8(±3.54)[3]
British Mean(±SD)	103.1(±4.96)[3]
95% Confidence Interval	-1.980 to 2.474
P value (Difference between Mean Hokien &Mean British)	**0.8248**
Hylam Mean(±SD)	104.7(±3.69)
Indian Mean(±SD)	102.3(±3.58)
95% Confidence Interval	-4.228 to -0.4697
P value (Difference between Mean Hylam &Mean Indian)	**0.0152**
Hylam Mean(±SD)	104.7(±3.69)[4]
British Mean(±SD)	103.1(±4.96)[4]
95% Confidence Interval	-3.871 to 0.6476
P value (Difference between Mean Hylam &Mean British)	**0.1587**
Indian Mean(±SD)	102.3(±3.58)[5]
British Mean(±SD)	103.1(±4.96)[5]
95% Confidence Interval	-1.499 to 2.973
P value (Difference between Mean Indian &Mean British)	**0.5119**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.2.2 Distances Related to Infraorbital Foramen

Table 42: Inter-Population Comparisons of: (D2B R, D2B L & D2A)

(a) The distance from the infraorbital foramen to the facial midline at the level of the supraorbital foramen: right side [D2B R].

(b) The distance from the infraorbital foramen to the facial midline at the level of the supraorbital foramen: left Side [D2B L].

(c) The distance from the right infraorbital foramen to the left infraorbital foramen [D2A].

	D2B R	D2B L	D2A
Hokien Mean(±SD)	25.66(±2.10)[1]	25.22(±2.43)	51.25(±3.85)
Hylam Mean(±SD)	26.08(±2.07)[1]	26.46(±2.29)	53.17(±3.10)
95% Confidence Interval	-0.6626 to 1.494	0.01598 to 2.456	0.1088 to 3.724
P value (Difference between Mean Hokien &Mean Hylam)	**0.4435**	**0.0472**	**0.0381**
Hokien Mean(±SD)	25.66(±2.10)[2]	25.22(±2.43)[5]	51.25(±3.85)[8]
Indian Mean(±SD)	25.17(±2.11)[2]	25.39(±1.68)[5]	50.84(±2.74)[8]
95% Confidence Interval	-1.586 to 0.5930	-0.9073 to 1.247	-2.139 to 1.319
P value (Difference between Mean Hokien &Mean Indian)	**0.3653**	**0.7536**	**0.6367**
Hokien Mean(±SD)	25.66(±2.10)	25.22(±2.43)[6]	51.25(±3.85)[9]
British Mean(±SD)	24.20(±2.45)	24.85(±2.41)[6]	50.00(±4.12)[9]
95% Confidence Interval	-2.642 to -0.2809	-1.613 to 0.8846	-3.308 to 0.8146
P value (Difference between Mean Hokien &Mean British)	**0.0161**	**0.5615**	**0.2309**
Hylam Mean(±SD)	26.08(±2.07)[3]	26.46(±2.29)	53.17(±3.10)
Indian Mean(±SD)	25.17(±2.11)[3]	25.39(±1.68)	50.84(±2.74)
95% Confidence Interval	-1.994 to 0.1690	-2.104 to -0.02824	-3.839 to -0.8141
P value (Difference between Mean Hylam &Mean Indian)	**0.0966**	**0.0443**	**0.0032**
Hylam Mean(±SD)	26.08(±2.07)	26.46(±2.29)	53.17(±3.10)
British Mean(±SD)	24.20(±2.45)	24.85(±2.41)	50.00(±4.12)
95% Confidence Interval	-3.050 to -0.7043	-2.816 to -0.3847	-5.047 to -1.279
P value (Difference between Mean Hylam &Mean British)	**0.0022**	**0.0108**	**0.0014**
Indian Mean(±SD)	25.17(±2.11)[4]	25.39(±1.68)[7]	50.84(±2.74)[10]
British Mean(±SD)	24.20(±2.45)[4]	24.85(±2.41)[7]	50.00(±4.12)[10]
95% Confidence Interval	-2.148 to 0.2185	-1.606 to 0.5380	-2.645 to 0.9713
P value (Difference between Mean Indian &Mean British)	**0.1081**	**0.3228**	**0.3581**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 43: Inter-Population Comparisons of: (D2C R, D2C L, D2E R & D2E L)

(a) The distance from the level of the infraorbital foramen to the anterior nasal spine: right side [D2C R].

(b) The distance from the level of the infraorbital foramen to the anterior nasal spine: left side [D2C L].

(c) The distance from the infraorbital foramen to the zygomatico-maxillary suture at the infraorbital rim: right side [D2E R].

(d) The distance from the infraorbital foramen to the zygomatico-maxillary suture at the infraorbital rim: left side [D2E L].

	D2C R	D2C L	D2E R	D2E L
Hokien Mean(±SD)	28.91(±2.48)	28.20(±3.23)	8.70(±1.68)[8]	8.44(±1.71)[11]
Hylam Mean(±SD)	30.63(±2.63)	30.01(±2.88)	9.29(±1.86)[8]	8.94(±1.80)[11]
95% Confidence Interval	0.3981 to 3.035	0.2354 to 3.397	-0.3310 to 1.501	-0.4125 to 1.405
P value (Difference between Mean Hokien &Mean Hylam)	**0.0116**	**0.0251**	**0.2062**	**0.2788**
Hokien Mean(±SD)	28.91(±2.48)[1]	28.20(±3.23)[4]	8.70(±1.68)	8.44(±1.71)[12]
Indian Mean(±SD)	29.33(±2.21)[1]	28.82(±2.06)[4]	7.23(±1.87)	7.54(±2.08)[12]
95% Confidence Interval	-0.8025 to 1.646	-0.7722 to 2.029	-2.390 to - 0.5544	-1.882 to 0.08436
P value (Difference between Mean Hokien &Mean Indian)	**0.4933**	**0.3729**	**0.0022**	**0.0724**
Hokien Mean(±SD)	28.91(±2.48)	28.20(±3.23)	8.70(±1.68)[9]	8.44(±1.71)[13]
British Mean(±SD)	30.49(±3.24)	29.91(±3.09)	7.97(±2.04)[9]	8.20(±1.92)[13]
95% Confidence Interval	0.08233 to 3.064	0.07824 to 3.346	-1.704 to 0.2271	-1.182 to 0.6965
P value (Difference between Mean Hokien &Mean British)	**0.0390**	**0.0403**	**0.1312**	**0.6070**
Hylam Mean(±SD)	30.63(±2.63)	30.01(±2.88)[5]	9.29(±1.86)	8.94(±1.80)
Indian Mean(±SD)	29.33(±2.21)	28.82(±2.06)[5]	7.23(±1.87)	7.54(±2.08)
95% Confidence Interval	-2.562 to - 0.02884	-2.481 to 0.1057	-3.019 to - 1.095	-2.400 to - 0.3910
P value (Difference between Mean Hylam &Mean Indian)	**0.0452**	**0.0712**	**< 0.0001**	**0.0073**
Hylam Mean(±SD)	30.63(±2.63)[2]	30.01(±2.88)[6]	9.29(±1.86)	8.94(±1.80)[14]
British Mean(±SD)	30.49(±3.24)[2]	29.91(±3.09)[6]	7.97(±2.04)	8.20(±1.92)[14]
95% Confidence Interval	-1.668 to 1.381	-1.647 to 1.440	-2.331 to - 0.3159	-1.700 to 0.2221
P value (Difference between Mean Hylam &Mean British)	**0.8510**	**0.8935**	**0.0109**	**0.1292**
Indian Mean(±SD)	29.33(±2.21)[3]	28.82(±2.06)[7]	7.23(±1.87)[10]	7.54(±2.08)[15]
British Mean(±SD)	30.49(±3.24)[3]	29.91(±3.09)[7]	7.97(±2.04)[10]	8.20(±1.92)[15]
95% Confidence Interval	-0.2991 to 2.602	-0.2743 to 2.442	-0.2752 to 1.743	-0.3756 to 1.688
P value (Difference between Mean Indian &Mean British)	**0.1175**	**0.1156**	**0.1508**	**0.2080**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 44: Inter-Population Comparisons of: (D2F R, D2F L, D2G R & D2G L)

(a) The distance from the infraorbital foramen to the infraorbital rim: right side [D2F R].

(b) The distance from the infraorbital foramen to the infraorbital rim: left side [D2F L].

(c) The distance from the infraorbital to the supraorbital foramina: right side [D2G R].

(d) The distance from the infraorbital to the supraorbital foramina: left side [D2G L].

	D2F R	D2F L	D2G R	D2G L
Hokien Mean(±SD)	8.35(±1.87)[1]	8.17(±1.36)[4]	44.15(±2.99)[8]	43.36(±2.81)[11]
Hylam Mean(±SD)	8.49(±1.57)[1]	8.47(±1.52)[4]	43.96(±2.94)[8]	44.28(±3.11)[11]
95% Confidence Interval	-0.7553 to 1.028	-0.4422 to 1.049	-1.719 to 1.348	-1.119 to 1.941
P value (Difference between Mean Hokien &Mean Hylam)	**0.7607**	**0.4187**	**0.8094**	**0.5929**
Hokien Mean(±SD)	8.35(±1.87)	8.17(±1.36)	44.15(±2.99)	43.36(±2.81)
Indian Mean(±SD)	6.89(±1.95)	6.84(±1.97)	40.43(±3.36)	40.40(±3.21)
95% Confidence Interval	-2.447 to -0.4740	-2.207 to -0.4599	-5.364 to -2.074	-5.028 to -1.910
P value (Difference between Mean Hokien &Mean Indian)	**0.0044**	**0.0034**	**< 0.0001**	**< 0.0001**
Hokien Mean(±SD)	8.35(±1.87)[2]	8.17(±1.36)[5]	44.15(±2.99)[9]	43.36(±2.81)[12]
British Mean(±SD)	7.54(±1.72)[2]	7.85(±2.13)[5]	43.28(±3.29)[9]	43.29(±3.25)[12]
95% Confidence Interval	-1.740 to 0.1164	-1.250 to 0.6002	-2.488 to 0.7612	-2.139 to 0.9986
P value (Difference between Mean Hokien &Mean British)	**0.0853**	**0.4850**	**0.2918**	**0.4699**
Hylam Mean(±SD)	8.49(±1.57)	8.47(±1.52)	43.96(±2.94)	44.28(±3.11)
Indian Mean(±SD)	6.89(±1.95)	6.84(±1.97)	40.43(±3.36)	40.40(±3.21)
95% Confidence Interval	-2.510 to -0.6829	-2.544 to -0.7290	-5.166 to -1.900	-5.513 to -2.247
P value (Difference between Mean Hylam &Mean Indian)	**0.0009**	**0.0006**	**< 0.0001**	**< 0.0001**
Hylam Mean(±SD)	8.49(±1.57)	8.47(±1.52)[6]	43.96(±2.94)[10]	44.28(±3.11)[13]
British Mean(±SD)	7.54(±1.72)	7.85(±2.13)[6]	43.28(±3.29)[10]	43.29(±3.25)[13]
95% Confidence Interval	-1.799 to -0.09737	-1.585 to 0.3293	-2.290 to 0.9344	-2.624 to 0.6616
P value (Difference between Mean Hylam &Mean British)	**0.0296**	**0.1943**	**0.4035**	**0.2368**
Indian Mean(±SD)	6.89(±1.95)[3]	6.84(±1.97)[7]	40.43(±3.36)	40.40(±3.21)
British Mean(±SD)	7.54(±1.72)[3]	7.85(±2.13)[7]	43.28(±3.29)	43.29(±3.25)
95% Confidence Interval	-0.3007 to 1.598	-0.05129 to 2.069	1.137 to 4.574	1.230 to 4.568
P value (Difference between Mean Indian &Mean British)	**0.1767**	**0.0618**	**0.0015**	**0.0010**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at α = 0.05; (P > 0.05).

Table 45: Inter-Population Comparisons of: (D2H R & D2H L)

(a) The distance (horizontal) from the infraorbital foramen to the supraorbital foramen: right side [D2H R].

(b) The distance (horizontal) from the infraorbital foramen to the supraorbital foramen: left side [D2H L].

	D2H R	D2H L
Hokien Mean(±SD)	-2.23(±4.04)[1]	-3.44(±3.27)[7]
Hylam Mean(±SD)	-2.04(±3.73)[1]	-3.19(±3.86)[7]
95% Confidence Interval	-1.842 to 2.214	-1.632 to 2.132
P value (Difference between Mean Hokien &Mean Hylam)	**0.8548**	**0.7909**
Hokien Mean(±SD)	-2.23(±4.04)[2]	-3.44(±3.27)[8]
Indian Mean(±SD)	-2.22(±3.13)[2]	-3.63(±3.69)[8]
95% Confidence Interval	-1.915 to 1.934	-2.037 to 1.659
P value (Difference between Mean Hokien &Mean Indian)	**0.9922**	**0.8386**
Hokien Mean(±SD)	-2.23(±4.04)[3]	-3.44(±3.27)[9]
British Mean(±SD)	-2.26(±3.99)[3]	-3.90(±4.50)[9]
95% Confidence Interval	-2.133 to 2.058	-2.534 to 1.605
P value (Difference between Mean Hokien &Mean British)	**0.9716**	**0.6547**
Hylam Mean(±SD)	-2.04(±3.73)[4]	-3.19(±3.86)[10]
Indian Mean(±SD)	-2.22(±3.13)[4]	-3.63(±3.69)[10]
95% Confidence Interval	-1.996 to 1.643	-2.444 to 1.566
P value (Difference between Mean Hylam &Mean Indian)	**0.8464**	**0.6624**
Hylam Mean(±SD)	-2.04(±3.73)[5]	-3.19(±3.86)[11]
British Mean(±SD)	-2.26(±3.99)[5]	-3.90(±4.50)[11]
95% Confidence Interval	-2.222 to 1.774	-2.920 to 1.491
P value (Difference between Mean Hylam &Mean British)	**0.8235***	**0.5188**
Indian Mean(±SD)	-2.22(±3.13)[6]	-3.63(±3.69)[12]
British Mean(±SD)	-2.26(±3.99)[6]	-3.90(±4.50)[12]
95% Confidence Interval	-1.944 to 1.850	-2.464 to 1.912
P value (Difference between Mean Indian &Mean British)	**0.9607**	**0.8016**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.2.3 Distances Related to Mental Foramen

Table 46: Inter-Population Comparisons of: (D3A R, D3A L, D3B R & D3B L)

(a) The distance from the mental foramen, to the symphysis menti: right side [D3A R].

(b) The distance from the mental foramen, to the symphysis menti: left side [D3A L].

(c) The distance from the mental foramen to the posterior border of the mandible: right side [D3B R].

(d) The distance from the mental foramen to the posterior border of the mandible: left side [D3B L].

	D3A R	D3A L	D3B R	D3B L
Hokien Mean(±SD)	27.66 (± 1.61)[1]	27.49 (± 1.59)[4]	69.27(±4.21)	69.74(±3.85)[10]
Hylam Mean(±SD)	28.20(±2.00)[1]	28.14(±1.93)[4]	72.00 (±4.37)	71.44 (±4.25)[10]
95% Confidence Interval	-0.4004 to 1.472	-0.2651 to 1.561	0.5107 to 4.950	-0.3959 to 3.799
P value (Difference between Mean Hokien &Mean Hylam)	**0.2566**	**0.1608**	**0.0168**	**0.1098**
Hokien Mean(±SD)	27.66 (± 1.61)[2]	27.49 (± 1.59)[5]	69.27(±4.21)[8]	69.74 (±3.85)[11]
Indian Mean(±SD)	27.05 (± 1.62)[2]	27.00 (± 1.84)[5]	68.78(±3.89)[8]	69.06 (±3.76)[11]
95% Confidence Interval	-1.447 to 0.2220	-1.379 to 0.4003	-2.587 to 1.603	-2.651 to 1.286
P value (Difference between Mean Hokien &Mean Indian)	**0.1472**	**0.2754**	**0.6401**	**0.4905**
Hokien Mean(±SD)	27.66 (± 1.61)	27.49 (± 1.59)[6]	69.27(±4.21)	69.74 (±3.85)
British Mean(±SD)	26.54 (± 2.55)	26.92 (± 2.49)[6]	71.98(± 5.04)	72.74 (±5.40)
95% Confidence Interval	-2.219 to -0.01724	-1.647 to 0.5118	0.3074 to 5.109	0.5811 to 5.428
P value (Difference between Mean Hokien &Mean British)	**0.0466**	**0.2968**	**0.0277**	**0.0160**
Hylam Mean(±SD)	28.20(±2.00)	28.14(±1.93)	72.00(± 4.37)	71.44 (±4.25)
Indian Mean(±SD)	27.05 (± 1.62)	27.00 (± 1.84[5]	68.78(±3.89)	69.06 (±3.76)
95% Confidence Interval	-2.089 to -0.2086	-2.112 to -0.1631	-5.361 to -1.084	-4.459 to -0.3087
P value (Difference between Mean Hylam &Mean Indian)	**0.0175**	**0.0229**	**0.0038**	**0.0251**
Hylam Mean(±SD)	28.20(±2.00)	28.14(±1.93)	72.00(±4.37)[9]	71.44 (±4.25)[12]
British Mean(±SD)	26.54 (± 2.55)	26.92 (± 2.49)	71.98(±5.04)[9]	72.74 (±5.40)[12]
95% Confidence Interval	-2.837 to -0.4713	-2.366 to -0.06550	-2.461 to 2.416	-1.208 to 3.814
P value (Difference between Mean Hylam &Mean British)	**0.0069**	**0.0387**	**0.9854**	**0.3032**
Indian Mean(±SD)	27.05 (± 1.62)[3]	27.00 (± 1.84)[7]	68.78(±3.89)	69.06 (±3.76)
British Mean(±SD)	26.54 (± 2.55)[3]	26.92 (± 2.49)[7]	71.98(± 5.04)	72.74 (±5.40)
95% Confidence Interval	-1.609 to 0.5985	-1.210 to 1.053	0.8739 to 5.526	1.283 to 6.091
P value (Difference between Mean Indian &Mean British)	**0.3633**	**0.8903**	**0.0079**	**0.0033**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.2.4 Distances Related to Mandibular Foramen

Table 47: Inter-Population Comparisons of: (D4A R, D4A L, D4B R & D4B L)

(a) The distance from the mandibular foramen to the inferior border of the mandible: right side [D4A R].

(b) The distance from the mandibular foramen to the inferior border of the mandible: left side [D4A L].

(c) The distance from the mandibular foramen to the condylar notch: right side [D4B R].

(d) The distance from the mandibular foramen to the condylar notch: left side [D4B L].

	D4A R	D4A L	D4B R	D4B L
Hokien Mean(±SD)	25.23(±3.39)[1]	24.79(±3.55)[4]	24.32(±3.21)[8]	24.05(±3.04)[12]
Hylam Mean(±SD)	24.87(±3.55)[1]	25.05(±3.81)[4]	22.90(±3.54)[8]	22.81(±3.54)[12]
95% Confidence Interval	-2.078 to 1.350	-1.639 to 2.166	-3.173 to 0.3189	-2.944 to 0.4678
P value (Difference between Mean Hokien &Mean Hylam)	**0.6720**	**0.7825**	**0.1072**	**0.1517**
Hokien Mean(±SD)	25.23(±3.39)	24.79(±3.55)	24.32(±3.21)[9]	24.05(±3.04)[13]
Indian Mean(±SD)	22.84(±3.78)	22.83(±4.00)	22.96(±3.81)[9]	22.67(±3.22)[13]
95% Confidence Interval	-4.248 to -0.5376	-3.916 to -0.01221	-3.183 to 0.4571	-2.996 to 0.2426
P value (Difference between Mean Hokien &Mean Indian)	**0.0124**	**0.0486**	**0.1393**	**0.0941**
Hokien Mean(±SD)	25.23(±3.39)	24.79(±3.55)[5]	24.32(±3.21)[10]	24.05(±3.04)[14]
British Mean(±SD)	23.20(±3.77)	23.44(±3.66)[5]	25.44(±3.34)[10]	25.07(±2.90)[14]
95% Confidence Interval	-3.885 to -0.1804	-3.211 to 0.5114	-0.5787 to 2.806	-0.5160 to 2.557
P value (Difference between Mean Hokien &Mean British)	**0.0321**	**0.1520***	**0.1929**	**0.1889***
Hylam Mean(±SD)	24.87(±3.55)	25.05(±3.81)	22.90(±3.54)[11]	22.81(±3.54)[15]
Indian Mean(±SD)	22.84(±3.78)	22.83(±4.00)	22.96(±3.81)[11]	22.67(±3.22)[15]
95% Confidence Interval	-3.848 to -0.2082	-4.246 to -0.2096	-1.837 to 1.965	-1.888 to 1.611
P value (Difference between Mean Hylam &Mean Indian)	**0.0296**	**0.0311**	**0.9465**	**0.8745**
Hylam Mean(±SD)	24.87(±3.55)[2]	25.05(±3.81)[6]	22.90(±3.54)	22.81(±3.54)
British Mean(±SD)	23.20(±3.770)[2]	23.44(±3.66)[6]	25.44(±3.34)	25.07(±2.90)
95% Confidence Interval	-3.486 to 0.1490	-3.544 to 0.3171	0.7612 to 4.320	0.5851 to 3.932
P value (Difference between Mean Hylam &Mean British)	**0.0712**	**0.0997**	**0.0059**	**0.0090**
Indian Mean(±SD)	22.84(±3.78)[3]	22.83(±4.00)[7]	22.96(±3.81)	22.67(±3.22)
British Mean(±SD)	23.20(±3.77)[3]	23.44(±3.66)[7]	25.44(±3.34)	25.07(±2.90)
95% Confidence Interval	-1.591 to 2.311	-1.365 to 2.594	0.6243 to 4.329	0.8120 to 3.983
P value (Difference between Mean Indian &Mean British)	**0.7132**	**0.5366**	**0.0097**	**0.0037**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 48: Inter-Population Comparisons of: (D4C R, D4C L, D4D R & D4D L)

(a) The distance from the mandibular foramen to the posterior border of the ramus at the same level: right side [D4C R].

(b) The distance from the mandibular foramen to the posterior border of the ramus at the same level: left side [D4C L].

(c) The distance from the mandibular foramen to the posterior border of the ramus at the level of the occlusal line: right side [D4D R].

(d) The distance from the mandibular foramen to the posterior border of the ramus at the level of the occlusal line: left Side [D4D L].

	D4C R	D4C L	D4D R	D4D L
Hokien Mean(±SD)	17.39(±1.84)[1]	17.14(±1.53)[3]	18.54(±2.66)[5]	18.28(±2.28)[8]
Hylam Mean(±SD)	17.85(±2.36)[1]	17.38(±2.05)[3]	18.40(±2.92)[5]	17.71(±2.76)[8]
95% Confidence Interval	-0.6280 to 1.558	-0.6877 to 1.178	-1.580 to 1.309	-1.869 to 0.7442
P value (Difference between Mean Hokien &Mean Hylam)	**0.3979**	**0.6007**	**0.8519**	**0.3925**
Hokien Mean(±SD)	17.39(±1.84)	17.14(±1.53)	18.54(±2.66)	18.28(±2.28)
Indian Mean(±SD)	15.59(±2.01)	15.86(±1.96)	16.97(±3.00)	16.73(±2.37)
95% Confidence Interval	-2.790 to -0.8033	-2.183 to -0.3649	-3.036 to -0.1050	-2.742 to -0.3406
P value (Difference between Mean Hokien &Mean Indian)	**0.0006**	**0.0068**	**0.0361**	**0.0128**
Hokien Mean(±SD)	17.39(±1.84)	17.14(±1.53)	18.54(±2.66)	18.28(±2.28)
British Mean(±SD)	15.89(±2.09)	15.73(±1.97)	16.84(±2.72)	16.51(±2.16)
95% Confidence Interval	-2.519 to -0.4838	-2.316 to -0.4917	-3.087 to -0.3088	-2.907 to -0.6136
P value (Difference between Mean Hokien &Mean British)	**0.0045**	**0.0032**	**0.0175**	**0.0032**
Hylam Mean(±SD)	17.85(±2.36)	17.38(±2.05)	18.40(±2.92)[6]	17.71(±2.76)[9]
Indian Mean(±SD)	15.59(±2.01)	15.86(±1.96)	16.97(±3.00)[6]	16.73(±2.37)[9]
95% Confidence Interval	-3.394 to -1.129	-2.555 to -0.4835	-2.966 to 0.09640	-2.308 to 0.3500
P value (Difference between Mean Hylam &Mean Indian)	**0.0002**	**0.0048**	**0.0657**	**0.1457**
Hylam Mean(±SD)	17.85(±2.36)	17.38(±2.05)	18.40(±2.92)	17.71(±2.76)[10]
British Mean(±SD)	15.89(±2.09)	15.73(±1.97)	16.84(±2.72)	16.51(±2.16)[10]
95% Confidence Interval	-3.120 to -0.8128	-2.688 to -0.6107	-3.021 to -0.1040	-2.478 to 0.08241
P value (Difference between Mean Hylam &Mean British)	**0.0012**	**0.0024**	**0.0362**	**0.0661**
Indian Mean(±SD)	15.59(±2.01)[2]	15.86(±1.96)[4]	16.97(±3.00)[7]	16.73(±2.37)[11]
British Mean(±SD)	15.89(±2.09)[2]	15.73(±1.97)[4]	16.84(±2.72)[7]	16.51(±2.16)[11]
95% Confidence Interval	-0.7643 to 1.355	-1.147 to 0.8872	-1.607 to 1.352	-1.391 to 0.9532
P value (Difference between Mean Indian &Mean British)	**0.5791**	**0.7990**	**0.8635**	**0.7098**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 49: Inter-Population Comparisons of: (D4E R, D4E L, D4F R & D4F L)

(a) The distance from the mandibular foramen to the internal oblique ridge at the level of the occlusal line: right side [D4E R].

(b) The distance from the mandibular foramen to the internal oblique ridge at the level of the occlusal line: left side [D4E L].

(c) The distance from the mandibular foramen to the occlusal line: right side [D4F R].

(d) The distance from the mandibular foramen to the occlusal line: left side [D4F L].

	D4E R	D4E L	D4F R	D4F L
Hokien Mean(±SD)	14.70(±2.30)[1]	15.00(±2.46)[4]	-4.68(±4.24)[7]	-4.72(±5.06)[13]
Hylam Mean(±SD)	14.87(±1.95)[1]	14.93(±2.07)[4]	-4.14(±3.59)[7]	-3.45(±3.49)[13]
95% Confidence Interval	-0.9338 to 1.269	-1.2506 to 1.097	-1.490 to 2.571	-0.9703 to 3.521
P value (Difference between Mean Hokien &Mean Hylam)	**0.7617**	**0.8969**	**0.5963**	**0.2603**
Hokien Mean(±SD)	14.70(±2.30)	15.00(±2.46)	-4.68(±4.24)[8]	-4.72(±5.06)[14]
Indian Mean(±SD)	13.48(±2.25)	12.99(±2.06)	-4.73(±3.30)[8]	-3.80(±3.17)[14]
95% Confidence Interval	-2.394 to -0.04193	-3.183 to -0.8393	-2.011 to 1.920	-1.264 to 3.100
P value (Difference between Mean Hokien &Mean Indian)	**0.0426**	**0.0011**	**0.9631**	**0.4031**
Hokien Mean(±SD)	14.70(±2.30)[2]	15.00(±2.46)[5]	-4.68(±4.24)[9]	-4.72(±5.06)[15]
British Mean(±SD)	15.11(±2.39)[2]	14.93(±1.75)[5]	-4.23(±3.10)[9]	-3.80(±2.27)[15]
95% Confidence Interval	-0.8058 to 1.618	-1.174 to 1.032	-1.462 to 2.377	-1.108 to 2.945
P value (Difference between Mean Hokien &Mean British)	**0.5049**	**0.8984**	**0.6352**	**0.3680**
Hylam Mean(±SD)	14.87(±1.95)	14.93(±2.07)	-4.14(±3.59)[10]	-3.45(±3.49)[16]
Indian Mean(±SD)	13.48(±2.25)	12.99(±2.06)	-4.73(±3.30)[10]	-3.80(±3.17)[16]
95% Confidence Interval	-2.476 to -0.2958	-3.002 to -0.8679	-2.369 to 1.197	-2.079 to 1.365
P value (Difference between Mean Hylam &Mean Indian)	**0.0136**	**0.0006**	**0.5131**	**0.6794**
Hylam Mean(±SD)	14.87(±1.95)[3]	14.93(±2.07)[6]	-4.14(±3.59)[11]	-3.45(±3.49)[17]
British Mean(±SD)	15.11(±2.39)[3]	14.93(±1.75)[6]	-4.23(±3.10)[11]	-3.80(±2.27)[17]
95% Confidence Interval	-0.8901 to 1.367	-0.9851 to 0.9965	-1.815 to 1.649	-1.878 to 1.164
P value (Difference between Mean Hylam &Mean British)	**0.6737**	**0.9909**	**0.9239**	**0.6405**
Indian Mean(±SD)	13.48(±2.25)	12.99(±2.06)	-4.73(±3.30)[12]	-3.80(±3.17)[18]
British Mean(±SD)	15.11(±2.39)	14.93(±1.75)	-4.23(±3.10)[12]	-3.80(±2.27)[18]
95% Confidence Interval	0.4227 to 2.826	0.9518 to 2.930	-1.152 to 2.158	-1.424 to 1.425
P value (Difference between Mean Indian &Mean British)	**0.0089**	**0.0002**	**0.5453**	**0.9993**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 50: Inter-Population Comparisons of: (D4G R, D4G L, D4H R & D4H L)

(a) The distance from the posterior border of the ramus to the internal oblique ridge at the level of the occlusal line: right Side [D4G R].

(b) The distance from the posterior border of the ramus to the internal oblique ridge at the level of the occlusal line: left Side [D4G L].

(c) The distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line: right side [D4H R].

(d) The distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line: left side [D4H L].

	D4G R	D4G L	D4H R	D4H L
Hokien Mean(±SD)	31.78(±2.86)[1]	32.24(±2.98)[4]	35.61(±2.78)[6]	35.96(±2.93)[8]
Hylam Mean(±SD)	32.65(±2.78)[1]	32.19(±2.74)[4]	35.37(±2.73)[6]	36.04(±5.85)[8]
95% Confidence Interval	-0.5871 to 2.326	-1.520 to 1.434	-1.663 to 1.186	-2.310 to 2.469
P value (Difference between Mean Hokien &Mean Hylam)	**0.2370**	**0.9541**	**0.7389**	**0.9472**
Hokien Mean(±SD)	31.78(±2.86)	32.24(±2.98)	35.61(±2.78)	35.96(±2.93)
Indian Mean(±SD)	29.45(±2.30)	29.24(±2.71)	32.69(±2.64)	32.84(±2.99)
95% Confidence Interval	-3.667 to -0.9851	-4.468 to -1.525	-4.314 to -1.512	-4.647 to -1.590
P value (Difference between Mean Hokien &Mean Indian)	**0.0010**	**0.0001**	**0.0001**	**0.0001**
Hokien Mean(±SD)	31.78(±2.86)[2]	32.24(±2.98)	35.61(±2.78)	35.96(±2.93)
British Mean(±SD)	30.71(±2.98)[2]	30.01(±4.35)	32.84(±2.97)	32.98(±3.53)
95% Confidence Interval	-2.574 to 0.4443	-4.149 to -0.2961	-4.255 to -1.281	-4.653 to -1.301
P value (Difference between Mean Hokien &Mean British)	**0.1632**	**0.0245**	**0.0004**	**0.0008**
Hylam Mean(±SD)	32.65(±2.78)	32.19(±2.74)	35.37(±2.73)	36.04(±5.83)
Indian Mean(±SD)	29.45(±2.30)	29.24(±2.71)	32.69(±2.64)	32.84(±2.99)
95% Confidence Interval	-4.512 to -1.879	-4.362 to -1.546	-4.064 to -1.286	-5.597 to -0.7994
P value (Difference between Mean Hylam &Mean Indian)	**< 0.0001**	**< 0.0001**	**0.0003**	**0.0099**
Hylam Mean(±SD)	32.65(±2.78)	32.19(±2.74)	35.37(±2.73)	36.04(±5.85)
British Mean(±SD)	30.71(±2.98)	30.01(±4.35)	32.84(±2.97)	32.98(±3.53)
95% Confidence Interval	-3.423 to -0.4467	-4.058 to -0.3015	-4.005 to -1.055	-5.551 to -0.5612
P value (Difference between Mean Hylam &Mean British)	**0.0117**	**0.0237**	**0.0011**	**0.0172**
Indian Mean(±SD)	29.45(±2.30)[3]	29.24(±2.71)[5]	32.69(±2.64)[7]	32.84(±2.99)[9]
British Mean(±SD)	30.71(±2.98)[3]	30.01(±4.35)[5]	32.84(±2.97)[7]	32.98(±3.53)[9]
95% Confidence Interval	-0.1137 to 2.636	-1.100 to 2.648	-1.308 to 1.598	-1.547 to 1.831
P value (Difference between Mean Indian &Mean British)	**0.0715**	**0.4116**	**0.8423**	**0.8672**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.1.3 The Correlation between the Obtuseness of the Mandibular Angle and the Ipsilateral Measurement from the Mental Foramen to the Posterior Border of the Mandible on Both Sides of Each Population

Statistical analysis was performed using Compute Pearson Correlation Coefficient.

Table 51: The Correlation between the Obtuseness of the Mandibular Angle and the Ipsilateral Measurement from the Mental Foramen to the Posterior Border of the Mandible

Population	D3B R v G3 R	D3B L v G3 L
Hokien	-0.457	-0.411
Hylam	0.048	0.247
Indian	-0.057	0.091
British	-0.116	-0.147

Table 51 shows that there were no correlation between the obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible, on both sides in each population of the four populations, except on the both sides where the Hokien population exhibited a weak negative correlation.

8.1.4 Intra-Population Comparisons of Foraminal Positions With Respect to Age in Each of the Four Populations

Each population was divided based on Brothwell chart into four age groups, group 1 (17-25), group 2 (26-35), group 3 (36-45) and group 4 (> 45 years). Statistical analysis was performed using one-way ANOVA at $\alpha = 0.05$.

Summary: There were no statistically significant differences between the distances related to the supraorbital, infraorbital, mental or mandibular foramina with respect to the four age groups, in each of the four population groups. With a very few exceptions there were statistically significant differences between the age groups in the Hylam population in regard to the distance from the supraorbital foramen to the midline and to the infraorbital foramen and from the mental foramen to the symphysis menti and in the Hokien population in regard to the distance from the level of mandibular foramen to internal oblique ridge and to internal oblique ridge in relation to the distance from the posterior border of the ramus to internal oblique ridge at occlusal line at occlusal line but all these differences were not clinically relevant.

8.1.4.1 Distances Related to Supraorbital Foramen

Comparison of distances related to supraorbital foramen region with respect to age in each of the four populations as following:

a. The Distance from the Right to the Left Supraorbital Foramina (D1A)

Table 52: Distance D1A

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	47.11 (± 6.47)	48.14	39.09 to 55.14	0.4435
	Age Group2	41.86 (± 6.16)	42.61	37.95 to 45.77	
	Age Group3	43.66 (± 4.37)	43.37	38.24 to 49.09	
	Age Group4	43.39 (± 6.05)	43.32	35.87 to 50,90	
Hylam	Age Group1	41.35 (± 6.26)	41.20	34.78 to 47.93	0.0661
	Age Group2	47.21 (± 6.63)	49.42	42.47 to 51.96	
	Age Group3	47.45 (± 5.32)	46.67	43.00 to 52.90	
	Age Group4	52.03 (± 6.89)	49.39	43.47 to 60.58	
Indian	Age Group1	41.96 (± 3.41)	42.82	38.38 to 45.54	0.4393
	Age Group2	44.08 (± 4.83)	45.01	40.62 to 47.53	
	Age Group3	45.75 (± 5.85)	43.23	40.34 to 51.17	
	Age Group4	45.95 (± 3.66)	44.37	41.41 to 50.49	
British	Age Group1	42.48 (± 4.16)	44.00	38.63 to 46.32	0.2541
	Age Group2	43.64 (± 5.75)	44.60	39.78 to 47.50	
	Age Group3	38.54 (± 6.12)	40.12	32.11 to 44.96	
	Age Group4	39.19 (± 6.45)	35.31	31.19 to 47.20	

Table 52 shows that in each population there was no significant difference between the four age groups.

b. Supraorbital Foramen to Midline: Right Side (D1B R)

Table 53: Distance D1B R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	25.40 (± 4.16)	25.49	20.24 to 30.55	0.2930
	Age Group2	21.97 (± 3.96)	21.89	19.58 to 24.36	
	Age Group3	22.97 (± 1.77)	22.37	20.78 to 25.17	
	Age Group4	21.51 (± 3.13)	21.80	17.63 to 25.39	
Hylam	Age Group1	21.34 (± 3.11)	20.60	18.46 to 24.22	0.0486
	Age Group2	24.35 (± 3.20)	25.31	22.06 to 26.63	
	Age Group3	23.44 (± 2.64)	23.06	21.23 to 25.65	
	Age Group4	26.29 (± 2.44)	25.59	23.26 to 29.32	
	Age Group1	21.34 (± 3.11)	20.60	18.46 to 24.22	0.0145
	Age Group4	26.29 (± 2.44)	25.59	23.26 to 29.32	
Indian	Age Group1	20.63 (± 1.44)	20.58	19.12 to 22.14	0.0856
	Age Group2	22.78 (± 3.54)	23.28	20.25 to 25.31	
	Age Group3	24.84 (± 2.80)	24.24	22.25 to 27.42	
	Age Group4	24.16 (± 3.09)	23.72	20.33 to 27.99	
British	Age Group1	22.42 (± 2.31)	22.73	20.49 to 24.35	0.1845
	Age Group2	23.66 (± 3.25)	24.06	21.47 to 25.84	
	Age Group3	20.35 (± 2.77)	21.38	17.45 to 23.25	
	Age Group4	21.46 (± 3.62)	19.02	16.97 to 25.95	

Table 53 shows that in each population there was no significant difference between the four age groups except the Hylam group where there was a significant difference between age groups 1 & 4. (P= 0.0145), with overall (P=0.0486)

c. Supraorbital Foramen to Midline: Left side (D1B L)

Table 54: Distance D1B L

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	22.84 (± 3.90)	23.77	18.00 to 27.69	0.3576
	Age Group2	20.53 (± 2.91)	20.44	18.84 to 22.21	
	Age Group3	21.58 (± 3.49)	21.30	17.24 to 25.92	
	Age Group4	23.06 (± 2.98)	21.76	19.37 to 26.76	
Hylam	Age Group1	21.49 (± 3.33)	22.60	17.99 to 24.99	0.2497
	Age Group2	23.91 (± 4.26)	23.48	20.86 to 26.96	
	Age Group3	24.92 (± 3.36)	24.00	22.11 to 27.73	
	Age Group4	25.91 (± 3.92)	25.54	21.05 to 30.78	
Indian	Age Group1	22.01 (± 3.27)	23.27	18.58 to 25.44	0.8876
	Age Group2	22.66 (± 4.11)	22.92	19.72 to 25.61	
	Age Group3	23.25 (± 4.03)	20.52	19.52 to 26.98	
	Age Group4	21.77 (± 1.44)	21.49	19.99 to 23.56	
British	Age Group1	22.52 (± 2.73)	21.07	19.99 to 25.05	0.6843
	Age Group2	21.86 (± 2.90)	21.79	19.79 to 23.93	
	Age Group3	20.25 (±3.58)	20.35	16.49 to 24.02	
	Age Group4	21.11 (± 5.28)	19.24	14.56 to 27.66	

Table 54 shows that in each population there was no significant difference between the four age groups.

d. Supraorbital Foramen to Temporal Crest: Right Side (D1C R)

Table 55: Distance D1C R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	22.04 (± 3.97)	23.16	17.11 to 26.98	0.2261
	Age Group2	24.61 (± 3.10)	24.30	22.89 to 26.33	
	Age Group3	23.56 (± 2.53)	23.49	20.43 to 26.70	
	Age Group4	26.14(± 3.04)	26.30	22.37 to 29.92	
Hylam	Age Group1	25.79 (± 3.23)	25.50	22.80 to 28.78	0.3315
	Age Group2	22.66 (± 2.99)	22.98	20.52 to 24.80	
	Age Group3	23.45 (± 2.79)	22.99	21.12 to 25.78	
	Age Group4	23.80 (± 5.11)	21.91	17.45 to 30.14	
Indian	Age Group1	27.52 (± 2.78)	26.54	24.95 to 30.10	0.7027
	Age Group2	26.75 (± 2.49)	26.84	24.97 to 28.53	
	Age Group3	25.89 (± 3.35)	26.22	23.08 to 28.69	
	Age Group4	26.19 (± 2.35)	26.25	23.28 to 29.11	
British	Age Group1	27.12 (± 2.78)	26.36	24.54 to 29.69	0.9284
	Age Group2	27.26 (± 3.72)	27.89	24.76 to 29.76	
	Age Group3	27.99 (± 3.54)	27.58	24.27 to 31.70	
	Age Group4	26.61 (± 3.64)	25.82	22.09 to 31.13	

Table 55 shows that in each population there was no significant difference between the four age groups.

e. Supraorbital Foramen to Temporal Crest: Left side (D1C L)

Table 56: Distance D1C L

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	22.14 (± 3.65)	20.32	17.62 to 26.67	0.3615
	Age Group2	24.43 (± 2.15)	23.67	23.19 to 25.67	
	Age Group3	23.40 (± 2.07)	23.73	20.83 to 25.98	
	Age Group4	23.64 (± 2.16)	23.42	20.97 to 26.32	
Hylam	Age Group1	25.76 (± 3.73)	27.75	22.31 to 29.21	0.1747
	Age Group2	22.00 (± 4.43)	22.20	18.83 to 25.17	
	Age Group3	22.41 (± 3.08)	21.15	19.84 to 24.99	
	Age Group4	21.43 (± 3.62)	22.45	16.94 to 25.92	
Indian	Age Group1	25.52 (± 3.55)	24.57	22.24 to 28.80	0.9744
	Age Group2	26.09 (± 3.56)	26.54	23.54 to 28.64	
	Age Group3	25.35 (±4.42)	25.39	21.66 to 29.05	
	Age Group4	25.53 (± 1.96)	25.80	23.09 to 27.96	
British	Age Group1	26.77 (± 2.88)	26.50	23.75 to 29.79	0.9672
	Age Group2	26.61 (± 3.70)	27.63	24.13 to 29.10	
	Age Group3	27.13 (± 3.91)	27.24	23.02 to 31.23	
	Age Group4	26.04 (± 3.65)	27.37	21.51 to 30.58	

Table 56 shows that in each population there was no significant difference between the four age groups.

f. Midline to Temporal Crest Through Supraorbital Foramen: Right Side (D1B R + D1C R)

Table 57: Distances D1B R + D1C R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	47.44 (± 3.73)	47.86	42.81 to 52.07	0.7879
	Age Group2	46.24 (± 2.06)	46.38	45.00 to 47.48	
	Age Group3	46.54 (± 3.51)	45.74	42.18 to 50.90	
	Age Group4	47.65 (± 4.26)	47.30	42.36 to 52.95	
Hylam	Age Group1	47.13 (± 2.16)	46.68	45.13 to 49.13	0.2171
	Age Group2	47.01 (± 2.64)	47.09	45.12 to 48.90	
	Age Group3	46.88 (± 3.02)	46.13	44.36 to 49.41	
	Age Group4	50.08 (± 3.98)	48.70	45.15 to 55.02	
Indian	Age Group1	47.27 (± 1.09)	47.11	46.12 to 48.41	0.1676
	Age Group2	49.54 (± 3.29)	48.37	47.18 to 51.89	
	Age Group3	50.27 (± 2.97)	49.90	47.52 to 53.02	
	Age Group4	50.35 (± 1.28)	50.79	48.77 to 51.94	
British	Age Group1	49.68 (± 2.63)	50.45	47.24 to 52.11	0.4283
	Age Group2	50.92 (± 3.68)	51.00	48.44 to 53.39	
	Age Group3	48.33 (± 4.86)	46.16	43.24 to 53.43	
	Age Group4	48.06 (± 3.82)	50.10	43.32 to 52.80	

Table 57 shows that in each population there was no significant difference between the four age groups.

g. Midline to Temporal Crest Through Supraorbital Foramen: Left Side (D1B L+D1C L)

Table 58: Distances D1B L + D1C L

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	44.99 (± 3.09)	44.09	41.15 to 48.83	0.7923
	Age Group2	45.10 (± 3.13)	45.73	43.21 to 46.99	
	Age Group3	44.98 (± 4.27)	44.84	39.69 to 50.28	
	Age Group4	46.71 (± 2.94)	44.99	43.06 to 50.36	
Hylam	Age Group1	46.92 (± 4.20)	46.34	42.51 to 51.33	0.7406
	Age Group2	45.91 (± 2.62)	45.55	44.03 to 47.78	
	Age Group3	47.33 (± 2.90)	46.53	44.91 to 49.75	
	Age Group4	47.35 (± 2.49)	47.61	44.26 to 50.43	
Indian	Age Group1	46.55 (± 1.24)	46.54	45.24 to 47.85	0.3878
	Age Group2	48.75 (± 3.50)	48.15	46.25 to 5126	
	Age Group3	48.39 (± 2.59)	47.26	46.00 to 50.78	
	Age Group4	47.30 (± 1.33)	47.46	45.65 to 48.95	
British	Age Group1	49.68 (± 2.36)	50.52	47.21 to 52.15	0.5405
	Age Group2	49.06 (± 4.10)	48.18	46.13 to 51.99	
	Age Group3	47.38 (± 3.46)	47.11	43.75 to 51.01	
	Age Group4	47.15 (± 3.66)	48.26	42.61 to 51.70	

Table 58 shows that in each population there was no significant difference between the four age groups.

h. Relative Position of the Supraorbital Foramen: Right Side

(D1B R / D1B R + D1C R)

Table 59: Distance D1B R / D1B R + D1C R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.54 (± 0.08)	0.52	0.44 to 0.63	0.2149
	Age Group2	0.47 (± 0.07)	0.48	0.43 to 0.52	
	Age Group3	0.49 (± 0.03)	0.49	0.46 to 0.53	
	Age Group4	0.45 (± 0.05)	0.44	0.39 to 0.51	
Hylam	Age Group1	0.46 (± 0.06)	0.45	0.40 to 0.51	0.1570
	Age Group2	0.52 (± 0.06)	0.52	0.47 to 0.56	
	Age Group3	0.50 (± 0.05)	0.50	0.46 to 0.54	
	Age Group4	0.53 (± 0.07)	0.53	0.44 to 0.61	
Indian	Age Group1	0.44 (± 0.03)	0.44	0.41 to 0.47	0.1894
	Age Group2	0.46 (± 0.05)	0.46	0.42 to 0.50	
	Age Group3	0.50 (± 0.05)	0.48	0.45 to 0.54	
	Age Group4	0.48 (± 0.05)	0.48	0.41 to 0.54	
British	Age Group1	0.45 (± 0.05)	0.46	0.41 to 0.50	0.5016
	Age Group2	0.46 (± 0.06)	0.46	0.42 to 0.51	
	Age Group3	0.42 (± 0.04)	0.42	0.38 to 0.47	
	Age Group4	0.44 (± 0.06)	0.45	0.37 to 0.52	

Table 59 shows that there was no significant difference between the four age groups in each of the four populations.

i. Relative Position of the Supraorbital Foramen: Left Side

(D1B L / D1B L + D1C L)

Table 60: Distance D1B L / D1B L + D1C L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.51 (± 0.08)	0.54	0.41 to 0.60	0.3467
	Age Group2	0.46 (± 0.05)	0.46	0.43 to 0.49	
	Age Group3	0.48 (± 0.04)	0.45	0.42 to 0.53	
	Age Group4	0.49 (± 0.05)	0.49	0.44 to 0.55	
Hylam	Age Group1	0.46 (± 0.07)	0.45	0.39 to 0.53	0.2586
	Age Group2	0.52 (± 0.09)	0.49	0.45 to 0.59	
	Age Group3	0.53 (± 0.06)	0.54	0.48 to 0.57	
	Age Group4	0.55 (± 0.07)	0.52	0.46 to 0.64	
Indian	Age Group1	0.47 (± 0.06)	0.49	0.41 to 0.54	0.9449
	Age Group2	0.46 (± 0.07)	0.45	0.41 to 0.51	
	Age Group3	0.48 (± 0.08)	0.45	0.40 to 0.56	
	Age Group4	0.46 (± 0.03)	0.45	0.42 to 0.50	
British	Age Group1	0.46 (± 0.05)	0.47	0.41 to 0.51	0.8315
	Age Group2	0.45 (± 0.05)	0.44	0.41 to 0.48	
	Age Group3	0.43 (± 0.07)	0.43	0.35 to 0.50	
	Age Group4	0.44 (± 0.08)	0.44	0.34 to 0.55	

Table 60 shows that in each group there was no significant difference between the four age groups.

8.1.4.2 Distances Related to Infraorbital Foramen

Comparison of distances related to infraorbital foramen with respect to age in each of the four populations as following:

a. The distance from the right to the left infraorbital foramina (D2A)

Table 61: Distance D2A

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	54.15 (± 2.04)	54.07	51.63 to 56.68	0.0726
	Age Group2	50.07 (± 4.03)	49.88	47.84 to 52.31	
	Age Group3	49.25 (± 4.15)	50.35	44.10 to 54.40	
	Age Group4	53.08 (± 1.99)	54.38	50.61to 55.55	
Hylam	Age Group1	52.41 (± 3.49)	51.75	49.19 to 55.64	0.8333
	Age Group2	53.22 (± 4.08)	54.19	50.30 to 56.13	
	Age Group3	53.15 (± 2.22)	52.55	51.29 to 55.00	
	Age Group4	54.16 (± 1.76)	54.91	51.97 to 56.35	
Indian	Age Group1	51.87 (± 1.55)	51.97	50.44 to 53.30	0.5450
	Age Group2	50.29 (± 2.09)	49.76	48.79 to 51.78	
	Age Group3	51.25 (± 3.89)	51.91	48.00 to 54.51	
	Age Group4	49.84 (± 3.23)	49.14	45.83 to 53.84	
British	Age Group1	49.48 (± 2.89)	49.32	47.07 to 51.90	0.7339
	Age Group2	49.83 (± 5.53)	52.03	46.12 to 53.54	
	Age Group3	51.70 (± 3.81)	52.32	47.70 to 55.70	
	Age Group4	49.19 (± 2.83)	48.98	45.67 to 52.70	

Table 61 shows that in each population there was no significant difference between the four age groups.

b. The distance between the right and the left fronto-zygomatic sutures (D1E)

Table 62: Distance D1E

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	106.08 (± 4.06)	105.36	100.38 to 108.90	0.0393
	Age Group2	101.86 (± 2.92)	102.27	100.25 to 103.48	
	Age Group3	100.85 (± 1.78)	100.51	98.64 to 103.06	
	Age Group4	104.37 (± 5.31)	104.09	97.78 to 110.96	
Hylam	Age Group1	102.28 (± 1.72)	102.05	100.69 to 103.88	0.2463
	Age Group2	105.38 (± 4.61)	106.34	102.08 to 108.67	
	Age Group3	104.93 (± 3.94)	104.29	101.64 to 108.23	
	Age Group4	106.21 (± 2.24)	107.56	103.42 to 108.99	
Indian	Age Group1	102.46 (± 4.81)	103.35	98.01 to 106.91	0.8193
	Age Group2	103.13 (± 2.41)	103.83	101.40 to 104.85	
	Age Group3	101.60 (± 4.24)	101.25	98.06 to 105.14	
	Age Group4	101.70 (± 3.24)	102.32	97.67 to 105.72	
British	Age Group1	101.67 (± 4.17)	102.34	98.18 to 105.16	0.5884
	Age Group2	104.17 (± 6.05)	102.83	100.11 to 108.24	
	Age Group3	104.22 (± 4.97)	104.47	99.01 to 109.44	
	Age Group4	101.46 (± 3.61)	100.95	96.98 to 105.94	

Table 62 shows that in each population there was no significant difference between the four age groups.

c. Relative Position of the Infraorbital Foramen, Ratio (D2A / D1E)

Table 63: Distance D2A / D1E

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.51 (± 0.01)	0.51	0.49 to 0.53	0.6386
	Age Group2	0.49 (± 0.03)	0.49	0.47 to 0.51	
	Age Group3	0.49 (± 0.04)	0.49	0.44 to 0.54	
	Age Group4	0.51 (± 0.02)	0.51	0.49 to 0.52	
Hylam	Age Group1	0.51 (± 0.03)	0.51	0.48 to 0.54	0.9262
	Age Group2	0.51 (± 0.04)	0.51	0.48 to 0.53	
	Age Group3	0.51 (± 0.01)	0.51	0.50 to 0.51	
	Age Group4	0.51 (± 0.02)	0.51	0.48 to 0.54	
Indian	Age Group1	0.51 (± 0.03)	0.50	0.48 to 0.53	0.4846
	Age Group2	0.49 (± 0.02)	0.49	0.47 to 0.50	
	Age Group3	0.50 (± 0.04)	0.50	0.47 to 0.54	
	Age Group4	0.49 (± 0.02)	0.49	0.47 to 0.51	
British	Age Group1	0.49 (± 0.03)	0.50	0.46 to 0.51	0.6818
	Age Group2	0.48 (± 0.03)	0.48	0.46 to 0.50	
	Age Group3	0.50 (± 0.02)	0.50	0.47 to 0.52	
	Age Group4	0.49 (± 0.03)	0.50	0.45 to 0.52	

Table 63 shows that in each population there was no significant difference between the four age groups.

d. Distance from the Supraorbital to the Infraorbital Foramina (Vertically): Right Side (D2G R)

Table 64: Distance D2G R

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	45.07 (± 2.56)	45.22	41.90 to 48.25	0.7768
	Age Group2	43.61 (± 3.21)	43.26	41.83 to 45.39	
	Age Group3	44.23 (± 3.28)	45.09	40.16 to 48.30	
	Age Group4	44.76 (± 2.97)	44.35	41.07 to 48.45	
Hylam	Age Group1	41.54 (± 1.77)	41.81	39.91 to 43.17	0.0373
	Age Group2	45.59 (± 3.06)	45.07	43.40 to 47.77	
	Age Group3	43.77 (± 3.13)	43.95	41.15 to 46.39	
	Age Group4	44.42 (± 1.64)	44.30	42.38 to 46.45	
	Age Group1	41.54 (± 1.77)	41.81	39.91 to 43.17	0.0068
	Age Group2	45.59 (± 3.06)	45.07	43.40 to 47.77	
Indian	Age Group1	41.37 (± 4.62)	40.58	37.09 to 45.64	0.8776
	Age Group2	40.07 (± 2.66)	39.90	38.17 to 41.97	
	Age Group3	40.30 (± 4.06)	39.69	36.90 to 43.69	
	Age Group4	40.05 (± 1.78)	39.80	37.84 to 42.25	
British	Age Group1	41.86 (± 2.50)	42.36	39.77 to 43.95	0.3920
	Age Group2	43.70 (± 3.83)	42.82	41.12 to 46.27	
	Age Group3	44.83 (± 3.35)	44.33	41.31 to 48.34	
	Age Group4	42.81 (± 2.88)	41.48	39.23 to 46.38	

Table 64 shows that in each population there was no significant difference between the four age groups except the Hylam group where there was a significant difference between the age groups 1 & 2 (P=0.0068), with overall (P=0.0373).

e. Distance from the Supraorbital to the Infraorbital Foramina (Vertically): Left Side (D2G L)

Table 65: Distance D2G L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	44.24 (± 2.28)	45.12	41.40 to 47.07	0.9396
	Age Group2	43.68 (± 3.47)	42.59	41.76 to 45.60	
	Age Group3	43.37 (± 2.54)	44.36	40.22 to 46.52	
	Age Group4	44.33 (± 1.65)	44.21	42.28 to 46.38	
Hylam	Age Group1	41.70 (± 2.25)	42.06	39.62 to 43.78	0.0679
	Age Group2	45.52 (± 3.37)	45.13	43.11 to 47.94	
	Age Group3	44.41 (± 3.16)	44.12	41.77 to 47.06	
	Age Group4	45.16 (± 1.69)	45.20	43.07 to 47.26	
Indian	Age Group1	41.32 (± 4.59)	42.98	37.08 to 45.57	0.8261
	Age Group2	39.94 (± 2.78)	40.46	37.95 to 41.93	
	Age Group3	40.52 (± 2.45)	39.76	37.64 to 43.41	
	Age Group4	39.80 (± 1.59)	39.82	37.83 to 41.77	
British	Age Group1	41.64 (± 3.04)	42.26	39.10 to 44.18	0.3980
	Age Group2	43.68 (± 3.64)	42.40	41.23 to 46.12	
	Age Group3	44.43 (± 2.63)	44.66	41.67 to 47.19	
	Age Group4	43.74 (± 3.23)	42.25	39.73 to 47.75	

Table 65 shows that in each population there was no significant difference between the four age groups.

8.1.4.3 Distances Related to Mental Foramen

Comparison of distances related to mental foramen with respect to age in each of the four populations as following:

a. Mental Foramen to Symphysis Menti: Right Side (D3A R)

Table 66: Distance D3A R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	28.40 (± 1.39)	28.05	26.68 to 30.12	0.4882
	Age Group2	27.80 (± 1.88)	28.08	26.76 to 28.84	
	Age Group3	27.19 (± 1.67)	27.66	25.20 to 29.19	
	Age Group4	26.96 (± 0.51)	27.04	26.33 to 27.60	
Hylam	Age Group1	28.03 (± 1.01)	28.04	27.09 to 28.97	0.1129
	Age Group2	27.14 (± 1.85)	26.76	25.81 to 28.46	
	Age Group3	28.86 (± 2.61)	28.21	26.68 to 31.05	
	Age Group4	29.49 (± 1.36)	29.18	27.79 to 31.18	
Indian	Age Group1	27.68 (± 1.82)	27.27	26.00 to 29.36	0.6818
	Age Group2	26.74 (± 1.40)	26.28	25.74 to 27.73	
	Age Group3	27.07 (± 1.61)	27.43	25.72 to 28.42	
	Age Group4	26.75 (± 2.04)	26.63	24.22 to 29.29	
British	Age Group1	25.54 (± 2.03)	26.40	23.85 to 52.11	0.6240
	Age Group2	26.80 (± 3.05)	27.12	24.75 to 53.39	
	Age Group3	26.75 (± 2.01)	26.52	24.64 to 53.43	
	Age Group4	27.34 (± 2.93)	27.18	23.69 to 30.98	

Table 66 shows that in each population there was no significant difference between the four age groups.

b. Mental Foramen to Symphysis Menti: Left side (D3A L)

Table 67: Distance D3A L

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	28.21 (± 1.11)	28.06	26.82 to 29.59	0.6160
	Age Group2	27.17 (± 1.71)	27.33	26.22 to 28.11	
	Age Group3	27.38 (± 1.99)	27.84	24.91 to 29.86	
	Age Group4	27.85 (± 1.32)	27.77	26.21 to 29.48	
Hylam	Age Group1	27.70 (± 1.16)	27.23	26.62 to 28.77	0.2482
	Age Group2	27.40 (± 1.59)	27.11	26.26 to 28.54	
	Age Group3	28.86 (± 2.68)	28.11	26.61 to 31.10	
	Age Group4	29.09 (± 1.66)	28.33	27.04 to 31.15	
Indian	Age Group1	26.76 (± 1.34)	26.87	25.52 to 28.00	0.5598
	Age Group2	26.46 (± 1.54)	25.85	25.36 to 27.56	
	Age Group3	27.62 (± 2.72)	27.51	25.35 to 29.89	
	Age Group4	27.43 (± 1.37)	27.17	25.74 to 29.13	
British	Age Group1	25.84 (± 1.92)	26.42	24.23 to 27.44	0.5052
	Age Group2	27.00 (± 2.81)	26.51	25.11 to 28.89	
	Age Group3	27.59 (± 2.49)	27.90	24.98 to 30.20	
	Age Group4	27.69 (± 2.67)	27.49	24.37 to 31.01	

Table 67 shows that in each population there was no significant difference between the four age groups.

c. Mental Foramen to Posterior Border of Mandible: Right Side (D3B R)

Table 68: Distance D3B R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	66.41 (± 4.23)	66.56	61.16 to 71.67	0.1763
	Age Group2	70.79 (± 3.83)	69.83	68.66 to 72.91	
	Age Group3	67.71 (± 4.74)	65.23	61.82 to 73.60	
	Age Group4	69.16 (± 3.87)	67.05	64.36 to 73.97	
Hylam	Age Group1	68.22 (± 3.11)	66.99	65.34 to 71.09	0.0642
	Age Group2	72.91 (± 1.99)	73.01	71.49 to 74.33	
	Age Group3	73.14 (± 5.17)	74.99	6882 to 77.46	
	Age Group4	73.67 (± 5.94)	73.06	66.29 to 81.05	
Indian	Age Group1	67.37 (± 5.01)	67.83	62.74 to 72.01	0.7650
	Age Group2	69.05 (± 3.84)	69.26	66.30 to 71.80	
	Age Group3	69.35 (± 2.13)	69.72	67.57 to 71.13	
	Age Group4	69.31 (± 5.10)	71.43	62.98 to 75.65	
British	Age Group1	70.82 (± 4.98)	71.75	66.66 to 74.98	0.8376
	Age Group2	71.81 (± 5.27)	70.53	68.26 to 75.35	
	Age Group3	73.19 (± 5.27)	72.80	67.65 to 78.72	
	Age Group4	72.79 (± 5.55)	74.20	65.91 to 79.68	

Table 68 shows that in each population there was no significant difference between the four age groups in each of the four population groups**.**

d. Mental Foramen to Posterior Border of Mandible: Left side (D3B L)

Table 69: Distance D3B L

	Age Groups	Mean (± SD)	Median1	95% Confidence Interval	P value
Hokien	Age Group1	66.86 (± 5.31)	66.51	60.27 to 73.45	0.1439
	Age Group2	70.73 (± 3.41)	70.16	68.84 to 72.62	
	Age Group3	68.16 (± 3.87)	66.65	63.36 to 72.97	
	Age Group4	71.21 (± 1.96)	71.04	68.79 to 73.64	
Hylam	Age Group1	68.01 (± 2.64)	68.53	65.57 to 70.45	0.0848
	Age Group2	71.85 (± 2.57)	72.68	70.02 to 73.69	
	Age Group3	72.71 (± 5.40)	73.74	68.20 to 77.23	
	Age Group4	73.39 (± 5.08)	71.38	67.09 to 79.70	
Indian	Age Group1	68.49(± 4.88)	68.08	63.98 to 73.00	0.9760
	Age Group2	69.33(± 3.48)	70.35	66.84 to 71.82	
	Age Group3	69.23(± 2.73)	69.69	66.94 to 71.51	
	Age Group4	69.04(± 5.07)	71.16	62.74 to 75.34	
British	Age Group1	71.91 (± 5.95)	71.67	66.93 to 76.88	0.5627
	Age Group2	71.57 (± 5.17)	71.16	68.10 to 75.04	
	Age Group3	75.27 (± 4.62)	76.12	70.42 to 80.11	
	Age Group4	73.63 (± 6.32)	73.43	65.78 to 81.49	

Table 69 shows that in each population there was no significant difference between the four age groups in each of the four population groups**.**

e. Mandible Size: Right Side (D3A R + D3B R)

Table 70: Mandible Size (D3A R + D3B R)

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	94.81 (± 4.83)	93.32	88.81 to 100.81	0.2779
	Age Group2	98.59 (± 4.55)	97.47	96.07 to 101.11	
	Age Group3	94.90 (± 5.15)	93.94	88.52 to 101.29	
	Age Group4	96.12 (± 4.21)	94.28	90.90 to 101.35	
Hylam	Age Group1	96.24 (± 3.51)	95.21	93.00 to 99.49	0.1002
	Age Group2	100.05 (± 2.68)	100.75	98.13 to 101.97	
	Age Group3	102.00 (± 7.17)	103.25	96.01 to 108.00	
	Age Group4	103.16 (± 6.65)	103.19	94.91 to 111.42	
Indian	Age Group1	95.05 (± 5.98)	95.08	89.52 to 100.58	0.9571
	Age Group2	95.79 (± 4.24)	95.59	92.76 to 98.82	
	Age Group3	96.42 (± 3.14)	97.82	93.79 to 99.04	
	Age Group4	96.06 (± 6.40)	97.93	88.12 to 104.01	
British	Age Group1	96.36 (± 5.89)	98.51	91.44 to 101.28	0.7189
	Age Group2	98.60 (± 7.63)	97.54	93.48 to 103.73	
	Age Group3	99.93 (± 5.96)	101.46	93.68 to 106.19	
	Age Group4	100.13 (± 7.02)	97.69	91.42 to 108.84	

Table 70 shows that in each population there was no significant difference between the four age groups in each of the four population groups**.**

f. Mandible Size: Left Side (D3A L + D3B L)

Table 71: Mandible Size (D3A L + D3B L)

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	95.07 (±6.10)	94.15	87.49 to 102.64	0.3776
	Age Group2	97.90 (± 4.11)	98.20	95.63 to 100.18	
	Age Group3	95.55 (± 4.28)	94.49	90.23 to 100.86	
	Age Group4	99.06 (± 2.96)	98.81	95.39 to 102.73	
Hylam	Age Group1	95.70 (± 3.23)	95.48	92.72 to 98.69	0.0959
	Age Group2	99.25 (± 3.70)	99.99	96.61 to 101.89	
	Age Group3	101.57 (± 6.73)	102.39	95.94 to 107.19	
	Age Group4	102.49 (± 6.37)	99.71	94.58 to 110.39	
Indian	Age Group1	95.25 (± 5.84)	94.49	89.84 to 100.65	0.9166
	Age Group2	95.79 (± 3.68)	95.56	93.16 to 98.42	
	Age Group3	96.85 (± 4.04)	96.84	93.47 to 100.23	
	Age Group4	96.48 (± 5.79)	97.88	89.29 to 103.67	
British	Age Group1	97.74 (± 6.56)	98.16	92.26 to 103.22	0.5077
	Age Group2	98.57 (± 7.21)	97.27	93.73 to 103.42	
	Age Group3	102.86 (± 6.53)	105.87	96.01 to 109.71	
	Age Group4	101.33 (± 7.87)	100.92	91.55 to 111.10	

Table 71 shows that in each population there was no significant difference between the four age groups**.**

g. Mental Foramen to Symphysis Menti (D3A R) In Relation to Mandible Size Right Side (D3A R + D3B R)

Table 72: Distance D3A R / D3A R + D3B R

	Age Groups	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.30 (± 0.01)	0.30	0.28 to 0.32	0.1538
	Age Group2	0.28 (± 0.02)	0.28	0.27 to 0.29	
	Age Group3	0.29 (± 0.02)	0.28	0.27 to 0.31	
	Age Group4	0.28 (± 0.01)	0.28	0.27 to 0.29	
Hylam	Age Group1	0.29 (± 0.01)	0.29	0.28 to 0.30	0.0249
	Age Group2	0.27 (± 0.01)	0.27	0.26 to 0.28	
	Age Group3	0.28 (± 0.01)	0.28	0.27 to 0.29	
	Age Group4	0.29 (± 0.01)	0.29	0.27 to 0.30	
	Age Group1	0.29 (± 0.01)	0.29	0.28 to 0.30	0.0066
	Age Group2	0.27 (± 0.01)	0.27	0.26 to 0.28	
Indian	Age Group1	0.29 (± 0.02)	0.29	0.28 to 0.31	0.2861
	Age Group2	0.28 (± 0.01)	0.28	0.27 to 0.29	
	Age Group3	0.28 (± 0.01)	0.28	0.27 to 0.29	
	Age Group4	0.28 (± 0.02)	0.28	0.26 to 0.30	
British	Age Group1	0.26 (± 0.02)	0.27	0.25 to 0.28	0.8591
	Age Group2	0.27 (± 0.02)	0.28	0.26 to 0.28	
	Age Group3	0.27 (± 0.02)	0.27	0.25 to 0.29	
	Age Group4	0.27 (± 0.02)	0.27	0.24 to 0.30	

Table 72 shows that in each population there was no significant difference between the four age groups in each of the four populations except the Hylam where there was a significant difference between the age groups 1 & 2 (P=0.0066), with overall (P=0.0249).

h. Mental Foramen to Symphysis Menti (D3A L) In Relation to Mandible Size Left Side (D3A L + D3B L)

Table 73: Distance D3A L / D3A L + D3B L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.30 (± 0.01)	0.30	0.28 to 0.31	0.0763
	Age Group2	0.28 (± 0.01)	0.28	0.27 to 0.29	
	Age Group3	0.29 (± 0.02)	0.29	0.26 to 0.31	
	Age Group4	0.28 (± 0.01)	0.28	0.27 to 0.29	
Hylam	Age Group1	0.29 (± 0.01)	0.29	0.28 to 0.30	0.2341
	Age Group2	0.28 (± 0.01)	0.27	0.27 to 0.28	
	Age Group3	0.02 (± 0.02)	0.29	0.27 to 0.30	
	Age Group4	0.28 (± 0.01)	0.29	0.27 to 0.30	
Indian	Age Group1	0.28 (± 0.01)	0.28	0.27 to 0.29	0.6918
	Age Group2	0.28 (± 0.02)	0.27	0.26 to 0.29	
	Age Group3	0.28 (± 0.02)	0.28	0.27 to 0.30	
	Age Group4	0.28 (± 0.01)	0.29	0.27 to 0.30	
British	Age Group1	0.27 (± 0.02)	0.27	0.25 to 0.28	0.6871
	Age Group2	0.27 (± 0.02)	0.28	0.26 to 0.28	
	Age Group3	0.27 (± 0.01)	0.27	0.25 to 0.28	
	Age Group4	0.27 (± 0.02)	0.27	0.25 to 0.30	

Table 73 shows that in each population there was no significant difference between the four age groups.

8.1.4.4 Distances Related to Mandibular Foramen

Comparison of distances related to mandibular foramen with respect to age in each of the four populations as following:

a. The Distance From the Level of Mandibular Foramen to Internal Oblique Ridge at Occlusal Line Right Side (D4K R)

Table 74: Distance D4K R

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	11.38 (± 2.80)	10.64	7.90 to 14.86	0.0083
	Age Group2	14.84 (± 2.07)	14.85	13.69 to 15.98	
	Age Group1	11.38 (± 2.80)	10.64	7.90 to 14.86	0.0310
	Age Group4	15.49 (± 2.12)	15.21	12.85 to 18.13	
	Age Group2	14.84 (± 2.07)	14.85	13.69 to 15.98	0.0020
	Age Group3	11.09 (± 1.76)	11.89	8.91 to 13.28	
	Age Group3	11.09 (± 1.76)	11.89	8.91 to 13.28	0.0073
	Age Group4	15.49 (± 2.12)	15.21	12.85 to 18.13	
Hylam	Age Group1	13.80 (± 1.00)	13.81	12.88 to 14.72	0.7109
	Age Group2	14.81 (± 3.34)	14.64	12.42 to 17.20	
	Age Group3	14.38 (± 1.68)	14.78	12.98 to 15.79	
	Age Group4	13.51 (± 1.75)	12.55	11.34 to 15.68	
Indian	Age Group1	11.92 (± 1.91)	12.27	10.15 to 13.68	0.7086
	Age Group2	13.26 (± 3.63)	12.49	10.66 to 15.86	
	Age Group3	12.36 (± 1.16)	12.57	11.40 to 13.33	
	Age Group4	13.11 (± 2.27)	12.13	10.29 to 15.93	
British	Age Group1	14.89 (± 2.61)	15.38	12.71 to 17.07	0.6760
	Age Group2	14.68 (± 2.74)	13.86	12.84 to 16.52	
	Age Group3	13.40 (± 2.05)	13.67	11.25 to 15.55	
	Age Group4	13.57 (±3.78)	13.83	8.88 to 18.25	

Table 74 shows that in each population there was no significant difference between the four age groups except the Hokien where there was a significant difference between the age groups 1 & 2 (P=0.0083), 1 & 4 (P=0.0310), 2 & 3 (P=0.0020) and 3 & 4 (P=0.0073), with overall (P=0.0015).

b. The Distance From the Level of Mandibular Foramen to Internal Oblique Ridge at Occlusal Line Left Side (D4K L)

Table 75: Distance D4K L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	12.75 (± 2.54)	12.94	9.60 to 15.90	0.3901
	Age Group2	14.79 (± 2.73)	15.21	13.28 to 16.30	
	Age Group3	13.83 (± 1.06)	13.57	12.51 to 15.15	
	Age Group4	15.04 (± 2.61)	15.40	11.80 to 18.29	
Hylam	Age Group1	14.55 (± 1.15)	14.36	13.49 to 15.61	0.7574
	Age Group2	14.96 (± 3.29)	15.47	12.61 to 17.31	
	Age Group3	13.74 (± 2.11)	13.88	11.97 to 15.50	
	Age Group4	14.09 (± 2.43)	14.28	11.07 to 17.11	
Indian	Age Group1	11.47 (± 1.47)	11.42	10.11 to 12.83	0.5559
	Age Group2	12.91 (± 2.98)	12.62	10.78 to 15.04	
	Age Group3	12.70 (± 1.74)	12.48	11.25 to 14.16	
	Age Group4	13.06 (± 2.23)	13.25	10.30 to 15.83	
British	Age Group1	15.22 (± 1.17)	15.10	14.24 to 16.20	0.5305
	Age Group2	13.17 (± 4.16)	13.45	10.37 to 15.60	
	Age Group3	13.68 (± 2.21)	14.41	11.35 to 16.00	
	Age Group4	13.96 (± 2.45)	14.73	10.92 to 17.01	

Table 75 shows that in each population there was no significant difference between the four age groups.

c. The Distance From the Posterior Border of The Ramus to Internal Oblique Ridge at Occlusal Line Right Side (D4G R)

Table 76: Distance D4G R

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	29.37 (± 4.28)	30.03	24.06 to 34.68	0.1213
	Age Group2	32.54(± 2.32)	32.54	31.26 to 33.82	
	Age Group3	30.88 (± 1.80)	30.42	28.65 to 33.12	
	Age Group4	32.78(± 2.70)	33.65	29.44 to 36.13	
Hylam	Age Group1	31.98 (± 2.66)	32.84	29.52 to 34.45	0.7969
	Age Group2	33.18(± 3.38)	33.56	30.76 to 35.60	
	Age Group3	32.25 (± 2.93)	31.77	29.80 to 34.69	
	Age Group4	33.14(± 1.56)	32.61	31.20 to 35.08	
Indian	Age Group1	28.11 (± 2.33)	28.82	25.95 to 30.27	0.1760
	Age Group2	30.56 (± 1.50)	30.43	29.49 to 31.63	
	Age Group3	29.53 (± 2.85)	30.29	27.15 to 31.91	
	Age Group4	28.97 (± 2.08)	29.73	26.39 to 31.56	
British	Age Group1	30.44 (± 2.87)	29.13	28.04 to 32.84	0.8899
	Age Group2	31.10 (± 2.94)	30.29	29.13 to 33.08	
	Age Group3	31.02 (± 2.62)	31.50	28.26 to 33.77	
	Age Group4	29.91 (± 4.28)	27.77	24.60 to 35.22	

Table 76 shows that in each group there was no significant difference between the four age groups in each of the four population groups.

d. The Distance From the Posterior Border of the Ramus to Internal Oblique Ridge at Occlusal Line Left Side (D4G L)

Table 77: Distance D4G L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	30.67 (± 3.19)	32.02	26.71 to 34.62	0.6315
	Age Group2	32.47 (± 3.12)	33.06	30.74 to 34.20	
	Age Group3	32.33 (± 1.81)	32.22	30.08 to 34.57	
	Age Group4	33.01 (± 3.55)	34.95	28.60 to 37.41	
Hylam	Age Group1	31.78 (± 2.04)	31.85	29.89 to 33.67	0.9725
	Age Group2	32.39 (± 3.56)	32.40	29.84 to 34.93	
	Age Group3	32.37 (± 2.78)	31.94	30.05 to 34.69	
	Age Group4	32.10 (± 2.36)	33.27	29.17 to 35.03	
Indian	Age Group1	28.14 (± 2.80)	28.30	25.55 to 30.73	0.6375
	Age Group2	29.81 (± 2.12)	29.32	28.29 to 31.33	
	Age Group3	29.63 (± 3.72)	29.57	26.53 to 32.74	
	Age Group4	29.00 (± 2.00)	28.45	26.52 to 31.49	
British	Age Group1	30.26 (± 2.97)	29.66	27.77 to 32.74	0.6627
	Age Group2	28.89 (± 5.79)	29.87	25.00 to 32.78	
	Age Group3	31.72 (± 3.17)	32.52	28.39 to 35.05	
	Age Group4	30.05 (± 4.15)	29.42	24.89 to 35.20	

Table 77 shows that in each population there was no significant difference between the four age groups.

e. The Distance from the Level of Mandibular Foramen to Internal Oblique Ridge (D4K R) In Relation to the Distance from the Posterior Border of the Ramus to Internal Oblique Ridge at Occlusal Line(D4G R) Right Side (D4K R / D4G R)

Table 78 a: Distance D4K R / D4G R

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.39 (± 0.06)	0.37	0.31 to 0.46	0.0395
	Age Group2	0.46 (± 0.06)	0.46	0.42 to 0.49	
	Age Group1	0.39 (± 0.06)	0.37	0.31 to 0.46	0.0386
	Age Group4	0.47 (± 0.04)	0.48	0.42 to 0.53	
	Age Group2	0.46 (± 0.06)	0.46	0.42 to 0.49	0.0047
	Age Group3	0.36 (± 0.05)	0.38	0.30 to 0.42	
	Age Group3	0.36 (± 0.05)	0.38	0.30 to 0.42	0.0048
	Age Group4	0.47 (± 0.04)	0.48	0.42 to 0.53	
Hylam	Age Group1	0.43 (± 0.03)	0.44	0.40 to 0.46	0.5704
	Age Group2	0.45 (± 0.07)	0.45	0.39 to 0.50	
	Age Group3	0.45 (± 0.05)	0.46	0.40 to 0.49	
	Age Group4	0.41 (± 0.04)	0.38	0.36 to 0.45	
Indian	Age Group1	0.42 (± 0.39)	0.44	0.39 to 0.46	0.8439
	Age Group2	0.43 (± 0.10)	0.42	0.36 to 0.50	
	Age Group3	0.42 (± 0.04)	0.41	0.38 to 0.46	
	Age Group4	0.46 (± 0.11)	0.40	0.32 to 0.60	
British	Age Group1	0.49 (± 0.09)	0.48	0.42 to 0.57	0.3998
	Age Group2	0.47 (± 0.07)	0.46	0.42 to 0.52	
	Age Group3	0.43 (± 0.04)	0.44	0.39 to 0.47	
	Age Group4	0.44 (± 0.07)	0.47	0.35 to 0.54	

Table 78 shows that in each population there was no significant difference between the four age groups except the Hokien where there was a significant difference between the age groups 1 & 2 (P=0.0395), 1 & 4 (P=0.0386), 2 & 3 (P=0.0047) and 3 & 4 (P=0.0048), with overall (P=00.0047).

f. The Distance from the Level of Mandibular Foramen to Internal Oblique Ridge (D4K L) In Relation to the Distance from the Posterior Border of the Ramus to Internal Oblique Ridge at Occlusal Line(D4G L) Left Side (D4K L / (D4G L)

Table 79: Distance D4K R / D4G L

	Age Group	Mean (± SD)	Median	95% Confidence Interval	P value
Hokien	Age Group1	0.41 (± 0.05)	0.40	0.35 to 0.47	0.5532
	Age Group2	0.45 (± 0.07)	0.44	0.41 to 0.49	
	Age Group3	0.43 (± 0.05)	0.41	0.37 to 0.48	
	Age Group4	0.45 (± 0.04)	0.44	0.40 to 0.51	
Hylam	Age Group1	0.46 (± 0.03)	0.45	0.43 to 0.49	0.5415
	Age Group2	0.46 (± 0.07)	0.47	0.41 to 0.51	
	Age Group3	0.43 (± 0.06)	0.43	0.37 to 0.48	
	Age Group4	0.44 (± 0.05)	0.44	0.37 to 0.50	
Indian	Age Group1	0.41 (± 0.02)	0.40	0.39 to 0.42	0.7023
	Age Group2	0.43 (± 0.07)	0.44	0.38 to 0.48	
	Age Group3	0.43 (± 0.06)	0.42	0.38 to 0.48	
	Age Group4	0.45 (± 0.09)	0.45	0.35 to 0.56	
British	Age Group1	0.51 (± 0.05)	0.52	0.46 to 0.55	0.2188
	Age Group2	0.44 (± 0.11)	0.45	0.37 to 0.51	
	Age Group3	0.43 (± 0.05)	0.44	0.38 to 0.48	
	Age Group4	0.46 (± 0.04)	0.47	0.42 to 0.51	

Table 79 shows that in each population there was no significant difference between the four age groups.

8.2 Scanning Method Using 3D Laser Scanning

8.2.1 Intra-Population Comparisons between Right and Left Sides in Each population Groups

Summary: There was no significant difference between the right and left sides in each of the four population groups in regard to the all distances related to the four foramina except that there were statistically significant differences between the right and left sides in the Hokien population in regard to the distance from the infraorbital foramen to the midline at the level of the supraorbital foramen and to the zygomatico maxillary suture and in the Hylam population in regard to the distance from the supraorbital foramen to the temporal crest, and from the mandibular foramen to the posterior border of the ramus but all these differences were not clinically relevant.

8.2.1.1 Distances Related to Supraorbital Foramen

In the following two tables the distances related to supraorbital region on right and left sides of each population are compared.

a. Supraorbital Foramen to Midline: Distance D1B

Table 80: Distance D1B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	22.54(±3.22)[1]	21.90(±3.25)[1]	-1.899 to 0.7015	**0.3519**
Hylam	23.23(±3.08)[2]	23.54(±3.49)[2]	-0.7367 to 1.079	**0.7021**
Indian	22.52(±3.24)[3]	22.40(±3.38)[3]	-1.687 to 1.444	**0.8748**
British	21.29(±3.19)[4]	20.99(±3.39)[4]	-1.195 to 0.6457	**0.5461**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Supraorbital Foramen to Temporal Crest: Distance D1C

Table 81: Distance D1C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	25.55(±3.26)^{1}	26.30(±2.61)^{1}	-0.6499 to 2.008	**0.3027**
Hylam	26.33(±3.23)	25.47(±3.80)	-1.461 to -0.1136	**0.0236**
Indian	28.48(±3.40)^{2}	28.01(±3.89)^{2}	-1.399 to 0.4586	**0.3082**
British	29.89(±3.18)^{3}	29.57(±3.39)^{3}	-1.229 to 0.3540	**0.2670**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.1.2 Distances Related to Infraorbital Foramen

In the following six tables the distances related to infraorbital region on right and left sides of each population are compared.

a. Infraorbital Foramen to Midline at the Level of the Supraorbital Foramen: Distance D2B

Table 82: Distance D2B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	25.79(±2.07)	24.65(±2.37)	-1.665 to -0.6283	**< 0.0001**
Hylam	26.08(±1.92)^{1}	25.71(±2.08)^{1}	-0.9210 to 0.1842	**0.1833**
Indian	24.67(±1.68)^{2}	24.36(±1.81)^{2}	-0.8356 to 0.2106	**0.2316**
British	23.77(±2.18)3	23.90(±2.27)^{3}	-0.4471 to 0.6989	**0.6566**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Infraorbital Foramen to Anterior Nasal Spine: Distance D2C

Table 83: Distance D2C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	28.51(±2.65)^{1}	27.89(±3.12)^{1}	-1.349 to 0.1171	**0.0964**
Hylam	29.59(±2.49)^{2}	29.51(±2.71)^{2}	-0.6649 to 0.5112	**0.7911**
Indian	28.50(±2.12)^{3}	28.60(±2.20)^{3}	-0.4783 to 0.6758	**0.7288**
British	29.32(±2.99)^{4}	29.44(±3.08)^{4}	-0.4644 to 0.7109	**0.6712**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

c. Infraorbital Foramen to Midline: Distance D2D

Table 84: Distance D2D

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	26.49(±1.90)	25.43(±2.46)	-1.688 to -0.4305	**0.0018**
Hylam	27.11(±1.93)[1]	26.66(±2.21)[1]	-0.9447 to 0.03244	**0.0661**
Indian	25.67(±1.53)[2]	25.57(±1.90)[2]	-0.7048 to 0.5020	**0.7335**
British	25.56(±2.03)[3]	25.86(±2.10)[3]	-0.3637 to 0.9606	**0.3642**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

d. Infraorbital Foramen to Infraorbital Rim: Distance D2F

Table 85: Distance D2F

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	7.51(±1.86)[1]	7.33(±1.72)[1]	-0.6151 to 0.2635	**0.4198**
Hylam	7.61(±1.78)[2]	7.58(±1.39)2	-0.5484 to 0.4736	**0.8821**
Indian	5.54(±1.95)[3]	5.78(±1.98)[3]	-0.1229 to 0.5894	**0.1908**
British	6.07(±1.70)[4]	6.22(±2.17)[4]	-0.3393 to 0.6251	**0.5491**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

e. Infraorbital to Supraorbital Foramen (Vertically): Distance D2G

Table 86: Distance D2G

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	43.94(±3.15)[1]	43.62(±2.83)[1]	-0.9031 to 0.2598	**0.2672**
Hylam	43.24(±3.40)[2]	43.38(±3.27)[2]	-0.6830 to 0.9552	**0.7365**
Indian	39.49(±3.20)[3]	39.71(±3.08)[3]	-0.3232 to 0.7774	**0.4056**
British	42.53(±3.27)[4]	42.33(±3.33)[4]	-0.8263 to 0.4404	**0.5380**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations ($P > 0.05$).

f. Infraorbital to Supraorbital Foramina (Horizontally): Distance D2H

Table 87: Distance D2H

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	-3.61(±3.80)[1]	-3.57(±3.21)[1]	-1.244 to 1.318	**0.9534**
Hylam	-2.79(±3.20)[2]	-2.37(±3.75)[2]	-0.5407 to 1.386	**0.3770**
Indian	-3.35(±3.50)[3]	-2.97(±4.01)[3]	-1.269 to 2.028	**0.6414**
British	-2.78(±3.82)[4]	-3.86(±3.86)[4]	-2.271 to 0.1139	**0.0746**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.1.3 Distances Related to Mental Foramen

In the following three tables the distances related to mental foramen region on right and left sides of each population are compared.

a. Mental Foramen to Symphysis Menti: Distance D3A

Table 88: Distance D3A

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	26.04(± 1.78)[1]	26.09(± 1.55)[1]	-0.4120 to 0.5060	**0.8356**
Hylam	26.52(± 2.01)[2]	26.78(± 2.02)[2]	-0.1143 to 0.6283	**0.1675**
Indian	25.58(± 1.84)[3]	25.50(± 1.45)[3]	-0.7049 to 0.5429	**0.7925**
British	25.16(± 2.39)[4]	25.55(± 2.57)[4]	-0.1016 to 0.8783	**0.1158**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Mental Foramen to Posterior Border of the Ramus: Distance D3B

Table 89: Distance D3B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	69.73(± 4.40)[1]	70.22(±3.77)[1]	-0.3645 to 1.350	**0.2493**
Hylam	72.57(± 4.50)[2]	71.98(±4.44)[2]	-1.342 to 0.1623	**0.1196**
Indian	69.55(± 4.11)[3]	69.49(±4.15)[3]	-0.8519 to 0.7379	**0.8844**
British	72.68(± 5.24)[4]	72.79(±5.33)[4]	-0.8316 to 1.040	**0.8218**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

c. Mental Foramen to Inferior Border of the Mandible: Distance D3C

Table 90: Distance D3C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	15.05 (± 1.49)[1]	14.75 (± 1.56)[1]	-0.6893 to 0.07795	**0.1140**
Hylam	15.76 (± 1.46)[2]	15.57 (± 1.28)[2]	-0.5921 to 0.2028	**0.3248**
Indian	14.06 (± 1.70)[3]	13.86 (± 1.50)[3]	-0.7414 to 0.3441	**0.4601**
British	14.40 (± 1.49)[4]	14.09 (± 1.35)[4]	-0.6559 to 0.04991	**0.0896**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.1.4 Distances Related to Mandibular Foramen

In the following eight tables the distances related to mandibular foramen region on right and left sides of each population are compared.

a. Mandibular Foramen to Inferior Border of the Mandible: Distance D4A

Table 91: Distance D4A

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	23.70(±3.58)[1]	22.96(±3.48)[1]	-1.521 to 0.02199	**0.0564**
Hylam	23.00(±3.39)[2]	22.36(±3.42)[2]	-1.549 to 0.2597	**0.1556**
Indian	21.48(±3.90)[3]	20.88(±4.06)[3]	-1.473 to 0.2772	**0.1729**
British	22.55(±3.79)[4]	21.75(±4.04)[4]	-1.697 to 0.1018	**0.0801**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

b. Mandibular Foramen to the condylar Notch: Distance D4B

Table 92: Distance D4B

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	24.81(±3.37)[1]	24.28(±3.19)[1]	-1.181 to 0.1274	**0.1103**
Hylam	24.09(±3.56)[2]	23.48(±3.68)[2]	-1.283 to 0.05860	**0.0721**
Indian	23.92(±3.97)[3]	23.47(±3.30)[3]	-1.218 to 0.3148	**0.2379**
British	25.86(±3.72)[4]	25.79(±2.95)[4]	-0.8679 to 0.7289	**0.8599**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

c. Mandibular Foramen to Posterior Border of the Ramus at the Same Level: Distance D4C

Table 93: Distance D4C

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	16.45(±1.99)[1]	16.44(±1.91)[1]	-0.6026 to 0.5926	**0.9865**
Hylam	16.93(±2.17)	16.40(±1.90)	-1.015 to -0.04659	**0.0328**
Indian	14.78(±2.25)[2]	15.04(±2.64)[2]	-0.3468 to 0.8820	**0.3804**
British	14.65(±2.52)[3]	14.63(±2.42)[3]	-0.7550 to 0.4558	**0.6167**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

d. Mandibular Foramen to Posterior Border of the Ramus at Occlusal Line: Distance D4D

Table 94: Distance D4D

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	16.50(±2.44)[1]	16.15(±2.41)[1]	-1.339 to 0.6401	**0.4760**
Hylam	16.94(±2.54)	16.29(±2.13)	-1.249 to -0.05885	**0.0324**
Indian	14.36(±2.33)[2]	14.74(±2.91)[2]	-0.3212 to 1.084	**0.2762**
British	15.47(±3.25)[3]	14.98(±2.56)[3]	-1.665 to 0.6935	**0.4066**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

e. Mandibular Foramen to Internal Oblique Ridge at Occlusal Line: Distance D4E

Table 95: Distance D4E

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	14.63(±2.04)[1]	14.96(±2.45)[1]	-0.2449 to 0.9036	**0.2503**
Hylam	15.23(±2.06)[2]	15.34(±2.12)[2]	-0.3602 to 0.5789	**0.6375**
Indian	13.68(±1.99)[3]	13.54(±2.25)[3]	-0.7878 to 0.5061	**0.6593**
British	14.86(±2.54)[4]	14.76(±1.80)[4]	-0.7916 to 0.6016	**0.7823**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

f. Mandibular Foramen to Occlusal Line: Distance D4F

Table 96: Distance D4F

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	-2.53(±3.72)[1]	-2.44(±3.09)[1]	-1.228 to 1.402	**0.8929**
Hylam	-2.96(±4.91)[2]	-2.12(±3.12)[2]	-0.9931 to 2.664	**0.3577**
Indian	-1.54(±3.61)[3]	-2.04(±3.57)[3]	-1.782 to 0.7806	**0.4305**
British	-3.24(±3.72)[4]	-3.14(±3.45)[4]	-1.468 to 1.674	**0.8943**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

g. Internal Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Distance D4G

Table 97: Distance D4G

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	29.90(±2.83)[1]	30.29(±3.09)[1]	-0.2767 to 1.057	**0.2410**
Hylam	30.69(±2.86)[2]	30.45(±2.69)[2]	-0.8355 to 0.3588	**0.4210**
Indian	27.31(±2.53)[3]	26.99(±3.04)3	-1.030 to 0.3812	**0.3548**
British	28.68(±3.04)[4]	28.60(±2.83)[4]	-0.7586 to 0.6001	**0.8131**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

h. External Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Distance D4H

Table 98: Distance D4H

Population	Mean (± SD)		95% Confidence Interval	P value
	Right	Left		
Hokien	34.33(±2.85)[1]	34.92(±3.91)[1]	-0.1840 to 1.363	**0.1299**
Hylam	34.32(±2.70)[2]	34.34(±2.40)[2]	-0.5459 to 0.5883	**0.9396**
Indian	31.90(±2.77)[3]	31.71(±2.90)[3]	-0.8662 to 0.4857	**0.5693**
British	32.46(±3.47)[4]	32.05(±3.69)[4]	-0.9616 to 0.1350	**0.1340**

Horizontal superscripts of the same numbers indicate no significant difference between the right and left sides in each of the populations. Paired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.2 Inter-Population Comparisons between the Ipsilateral Distances in Four Population Groups

In the following tables ipsilateral distances between the Hokien-Hylam, Hokien-Indian, Hokien-British, Hylam-Indian, Hylam-British and Indian-British populations are compared.

Summary: Where ipsilateral comparisons were carried out between four populations, there were some statistically significant differences with regard to the all maxillofacial foramina but all these differences were not clinically relevant.

8.2.2.1 Distances Related to Supraorbital Foramen

Table 99: Inter-Population Comparisons of: (D1B R, D1B L & D1A)

(a) The distance from the supraorbital foramen to midline: right side [D1B R].

(b) The distance from the supraorbital foramen to midline: left side [D1B L].

(c) The distance from right to left supraorbital foramen [D1A].

	D1B R	D1B L	D1A
Hokien Mean(±SD)	22.54(±3.22)[1]	21.90(±3.25)[6]	43.32(±5.47)[11]
Hylam Mean(±SD)	23.23(±3.08)[1]	23.54(±3.49)[6]	46.28(±6.41)[11]
95% Confidence Interval	-0.9825 to 2.364	-0.08321 to 3.455	-0.2680 to 6.219
P value (Difference between Mean Hokien &Mean Hylam)	**0.4116**	**0.0614**	**0.0714**
Hokien Mean(±SD)	22.54(±3.22)[2]	21.90(±3.25)[7]	43.32(±5.47)[12]
Indian Mean(±SD)	22.52(±3.24)[2]	22.40(±3.38)[7]	43.45(±4.90)[12]
95% Confidence Interval	-1.763 to 1.732	-1.283 to 2.200	-2.700 to 2.967
P value (Difference between Mean Hokien &Mean Indian)	**0.9858**	**0.6003**	**0.9250**
Hokien Mean(±SD)	22.54(±3.22)[3]	21.90(±3.25)[8]	43.32(±5.47)[13]
British Mean(±SD)	21.29(±3.19)[3]	20.99(±3.39)[8]	40.38(±5.80)[13]
95% Confidence Interval	-2.952 to 0.4558	-2.507 to 0.9311	-5.991 to 0.1288
P value (Difference between Mean Hokien &Mean British)	**0.1478**	**0.3626**	**0.0601**
Hylam Mean(±SD)	23.23(±3.08)[4]	23.54(±3.49)[9]	46.28(±6.41)[14]
Indian Mean(±SD)	22.52(±3.24)[4]	22.40(±3.38)[9]	43.45(±4.90)[14]
95% Confidence Interval	-2.368 to 0.9547	-3.050 to 0.5946	-5.880 to 0.1955
P value (Difference between Mean Hylam &Mean Indian)	**0.3979**	**0.1827**	**0.0661**
Hylam Mean(±SD)	23.23(±3.08)	23.54(±3.49)	46.28(±6.41)
British Mean(±SD)	21.29(±3.19)	20.99(±3.39)	40.38(±5.80)
95% Confidence Interval	-3.559 to -0.3189	-4.275 to -0.6729	-9.123 to -2.690
P value (Difference between Mean Hylam &Mean British)	**0.0198**	**0.0079**	**0.0005**
Indian Mean(±SD)	22.52(±3.24)[5]	22.40(±3.38)[10]	43.45(±4.90)
British Mean(±SD)	21.29(±3.19)[5]	20.99(±3.39)[10]	40.38(±5.80)
95% Confidence Interval	-2.923 to 0.4582	-3.020 to 0.5273	-5.920 to -0.2091
P value (Difference between Mean Indian &Mean British)	**0.1498**	**0.1649**	**0.0359**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 100: Inter-Population Comparisons of :(D1C R, D1C L & D1E)

(a) The distance from the supraorbital foramen to the temporal crest: right side [D1C R].

(b) The distance from the supraorbital foramen to the temporal crest: left side [D1C L].

(c) The distance between the right and left fronto-zygomatic sutures [D1E].

	D1C R	D1C L	D1E
Hokien Mean(±SD)	25.55(±3.26)[1]	26.30(±2.61)[3]	101.2(±3.44)[6]
Hylam Mean(±SD)	26.33(±3.23)[1]	25.47(±3.80)[3]	103.5(±3.58)[6]
95% Confidence Interval	-0.9390 to 2.511	-2.564 to 0.9070	-0.8887 to 0.9647
P value (Difference between Mean Hokien &Mean Hylam)	**0.3651**	**0.3429**	**0.9333**
Hokien Mean(±SD)	25.55(±3.26)	26.30(±2.61)[4]	101.2(±3.44)[7]
Indian Mean(±SD)	28.48(±3.40)	28.01(±3.89)[4]	101.1(±3.64)[7]
95% Confidence Interval	1.137 to 4.741	-0.05541 to 3.490	-0.9601 to 0.5799
P value (Difference between Mean Hokien &Mean Indian)	**0.0019**	**0.0573**	**0.6144**
Hokien Mean(±SD)	25.55(±3.26)	26.30(±2.61)	101.2(±3.44)[8]
British Mean(±SD)	29.89(±3.18)	29.57(±3.39)	101.4(±4.94)[8]
95% Confidence Interval	2.638 to 6.055	1.667 to 4.887	-0.6016 to 1.491
P value (Difference between Mean Hokien &Mean British)	**< 0.0001**	**0.0001**	**0.3858**
Hylam Mean(±SD)	26.33(±3.23)	25.47(±3.80)	103.5(±3.58)[9]
Indian Mean(±SD)	28.48(±3.40)	28.01(±3.89)	101.1(±3.64)[9]
95% Confidence Interval	0.4071 to 3.898	0.5059 to 4.586	-1.020 to 0.5639
P value (Difference between Mean Hylam &Mean Indian)	**0.0166**	**0.0154**	**0.5564**
Hylam Mean(±SD)	26.33(±3.23)	25.47(±3.80)	103.5(±3.58)[10]
British Mean(±SD)	29.89(±3.18)	29.57(±3.39)	101.4(±4.94)[10]
95% Confidence Interval	1.904 to 5.217	2.211 to 6.000	-0.6743 to 1.488
P value (Difference between Mean Hylam &Mean British)	**< 0.0001**	**< 0.0001**	**0.4407**
Indian Mean(±SD)	28.48(±3.40)[2]	28.01(±3.89)[5]	101.1(±3.64)[11]
British Mean(±SD)	29.89(±3.18)[2]	29.57(±3.39)[5]	101.4(±4.94)[11]
95% Confidence Interval	-0.3223 to 3.138	-0.3746 to 3.494	-0.1399 to 1.410
P value (Difference between Mean Indian &Mean British)	**0.1087**	**0.1118**	**0.1019**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.2.2 Distances Related to Infraorbital Foramen

Table 101: Inter-Population Comparisons of: (D2B R, D2B L & D2A)

(a) The distance from the infraorbital foramen to the midline at the level of the supraorbital foramen: right side [D2B R].

(b) The distance from the infraorbital foramen to the midline at the level of the supraorbital foramen: left side [Distance D2B L].

(c) The distance from right to left infraorbital foramen [D2A].

	D2B R	D2B L	D2A
Hokien Mean(±SD)	25.79(±2.07)[1]	24.65(±2.37)[3]	49.73(±3.86)[7]
Hylam Mean(±SD)	26.08(±1.92)[1]	25.71(±2.08)[3]	51.23(±3.39)[7]
95% Confidence Interval	-0.7459 to 1.319	-0.08789 to 2.217	-0.3788 to 3.377
P value (Difference between Mean Hokien &Mean Hylam)	**0.5806**	**0.0695**	**0.1155**
Hokien Mean(±SD)	25.79(±2.07)	24.65(±2.37)[4]	49.73(±3.86)[8]
Indian Mean(±SD)	24.67(±1.68)	24.36(±1.81)[4]	48.69(±2.51)[8]
95% Confidence Interval	-2.099 to -0.1484	-1.380 to 0.8009	-2.723 to 0.6414
P value (Difference between Mean Hokien &Mean Indian)	**0.0247**	**0.5970**	**0.2205**
Hokien Mean(±SD)	25.79(±2.07)	24.65(±2.37)[5]	49.73(±3.86)[9]
British Mean(±SD)	23.77(±2.18)	23.90(±2.27)[5]	48.03(±4.31)[9]
95% Confidence Interval	-3.120 to -0.9226	-1.949 to 0.4507	-3.815 to 0.4165
P value (Difference between Mean Hokien &Mean British)	**0.0005**	**0.2164**	**0.1133**
Hylam Mean(±SD)	26.08(±1.92)	25.71(±2.08)	51.23(±3.39)
Indian Mean(±SD)	24.67(±1.68)	24.36(±1.81)	48.69(±2.51)
95% Confidence Interval	-2.342 to -0.4783	-2.361 to -0.3476	-4.081 to -0.9988
P value (Difference between Mean Hylam &Mean Indian)	**0.0037**	**0.0092**	**0.0017**
Hylam Mean(±SD)	26.08(±1.92)	25.71(±2.08)	51.23(±3.39)
British Mean(±SD)	23.77(±2.18)	23.90(±2.27)	48.03(±4.31)
95% Confidence Interval	-3.368 to -1.247	-2.938 to -0.6897	-5.204 to -1.193
P value (Difference between Mean Hylam &Mean British)	**< 0.0001**	**0.0020**	**0.0023**
Indian Mean(±SD)	24.67(±1.68)[2]	24.36(±1.81)[6]	48.69(±2.51)[10]
British Mean(±SD)	23.77(±2.18)[2]	23.90(±2.27)[6]	48.03(±4.31)[10]
95% Confidence Interval	-1.903 to 0.1070	-1.520 to 0.6009	-2.482 to 1.165
P value (Difference between Mean Indian &Mean British)	**0.0789**	**0.3894**	**0.4726**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 102: Inter-Population Comparisons of: (D2C R, D2C L, D2D R & D2D L)

(a) The distance from the level of the infraorbital foramen to the anterior nasal spine: right side [D2C R].

(b) The distance from the level of the infraorbital foramen to the anterior nasal spine: left side [D2C L].

(c) The distance from the infraorbital foramen to the midline: right side [D2D R].

(d) The distance from the infraorbital foramen to the midline: left side [D2D L].

	D2C R	D2C L	D2D R	D2D L
Hokien Mean(±SD)	28.51(±2.65)[1]	27.89(±3.12)	26.49(±1.90)[12]	25.43(±2.46)
Hylam Mean(±SD)	29.59(±2.49)[1]	29.51(±2.71)	27.11(±1.93)[12]	26.66(±2.11)
95% Confidence Interval	-0.2438 to 2.411	0.1123 to 3.132	-0.3655 to 1.615	0.02044 to 2.436
P value (Difference between Mean Hokien &Mean Hylam)	**0.1077**	**0.0357**	**0.2116**	**0.0464**
Hokien Mean(±SD)	28.51(±2.65)[2]	27.89(±3.12)[7]	26.49(±1.90)[13]	25.43(±2.46)[16]
Indian Mean(±SD)	28.50(±2.12)[2]	28.60(±2.20)[7]	25.67(±1.53)[13]	25.57(±1.90)[16]
95% Confidence Interval	-1.242 to 1.236	-0.6833 to 2.107	-1.711 to 0.07169	-0.9960 to 1.273
P value (Difference between Mean Hokien &Mean Indian)	**0.9963**	**0.3114**	**0.0708**	**0.8079**
Hokien Mean(±SD)	28.51(±2.65)[3]	27.89(±3.12)[8]	26.49(±1.90)[14]	25.43(±2.46)[17]
British Mean(±SD)	29.32(±2.99)[3]	29.44(±3.08)[8]	25.56(±2.03)[14]	25.86(±2.10)[17]
95% Confidence Interval	-0.6466 to 2.272	-0.04964 to 3.153	-1.943 to 0.09071	-0.7495 to 1.612
P value (Difference between Mean Hokien &Mean British)	**0.2696**	**0.0573**	**0.0734**	**0.4675**
Hylam Mean(±SD)	29.59(±2.49)[4]	29.51(±2.71)[9]	27.11(±1.93)	26.66(±2.11)
Indian Mean(±SD)	28.50(±2.12)[4]	28.60(±2.20)[9]	25.67(±1.53)	25.57(±1.90)
95% Confidence Interval	-2.280 to 0.1068	-2.188 to 0.3664	-2.345 to -0.5437	-2.155 to -0.02495
P value (Difference between Mean Hylam &Mean Indian)	**0.0735**	**0.1588**	**0.0022**	**0.0450**
Hylam Mean(±SD)	29.59(±2.49)[5]	29.51(±2.71)[10]	27.11(±1.93)	26.66(±2.11)[18]
British Mean(±SD)	29.32(±2.99)[5]	29.44(±3.08)[10]	25.56(±2.03)	25.86(±2.10)[18]
95% Confidence Interval	-1.691 to 1.149	-1.570 to 1.429	-2.577 to -0.5258	-1.911 to 0.3176
P value (Difference between Mean Hylam &Mean British)	**0.7040**	**0.9250**	**0.0037**	**0.1577**
Indian Mean(±SD)	28.50(±2.12)[6]	28.60(±2.20)[11]	25.67(±1.53)[15]	25.57(±1.90)[19]
British Mean(±SD)	29.32(±2.99)[6]	29.44(±3.08)[11]	25.56(±2.03)[15]	25.86(±2.10)[19]
95% Confidence Interval	-0.5229 to 2.154	-0.5437 to 2.223	-1.037 to 0.8230	-0.7413 to 1.327
P value (Difference between Mean Indian &Mean British)	**0.2275**	**0.2292**	**0.8189**	**0.5728**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 103: Inter-Population Comparisons of :(D2F R, D2F L, D2G R & D2G L)

(a) The distance from the infraorbital foramen to the infraorbital rim: right side [D2F R].

(b) The distance from the infraorbital foramen to the infraorbital rim: left side [D2F L].

(c) The distance (vertical) from the infraorbital foramen to the supraorbital foramen: right side [D2G R].

(d) The distance (vertical) from the infraorbital foramen to the supraorbital foramen: left side [D2G L].

	D2F R	D2F L	D2G R	D2G L
Hokien Mean(±SD)	7.51(±1.86)[1]	7.33(±1.72)[3]	43.94(±3.15)[5]	43.62(±2.83)[8]
Hylam Mean(±SD)	7.61(±1.78)[1]	7.58(±1.39)[3]	43.24(±3.40)[5]	43.38(±3.27)[8]
95% Confidence Interval	-0.8353 to 1.044	-0.5642 to 1.049	-2.393 to 0.9955	-1.820 to 1.338
P value (Difference between Mean Hokien &Mean Hylam)	**0.8252**	**0.5497**	**0.4125**	**0.7612**
Hokien Mean(±SD)	7.51(±1.86)	7.33(±1.72)	43.94(±3.15)	43.62(±2.83)
Indian Mean(±SD)	5.54(±1.95)	5.78(±1.98)	39.49(±3.20)	39.71(±3.08)
95% Confidence Interval	-2.952 to -0.9829	-2.515 to -0.6012	-6.090 to -2.812	-5.429 to -2.375
P value (Difference between Mean Hokien &Mean Indian)	**0.0002**	**0.0019**	**< 0.0001**	**< 0.0001**
Hokien Mean(±SD)	7.51(±1.86)	7.33(±1.72)	43.94(±3.15)[6]	43.62(±2.83)[9]
British Mean(±SD)	6.07(±1.70)	6.22(±2.17)	42.53(±3.27)[6]	42.33(±3.33)[9]
95% Confidence Interval	-2.359 to -0.5153	-2.131 to -0.1054	-3.069 to 0.2477	-2.878 to 0.3139
P value (Difference between Mean Hokien &Mean British)	**0.0028**	**0.0311**	**0.0940**	**0.1133**
Hylam Mean(±SD)	7.61(±1.78)	7.58(±1.39)	43.24(±3.40)	43.38(±3.27)
Indian Mean(±SD)	5.54(±1.95)	5.78(±1.98)	39.49(±3.20)	39.71(±3.08)
95% Confidence Interval	-3.035 to -1.108	-2.682 to -0.9193	-5.459 to -2.046	-5.302 to -2.021
P value (Difference between Mean Hylam &Mean Indian)	**< 0.0001**	**0.0001**	**< 0.0001**	**< 0.0001**
Hylam Mean(±SD)	7.61(±1.78)	7.58(±1.39)	43.24(±3.40)[7]	43.38(±3.27)[10]
British Mean(±SD)	6.07(±1.70)	6.22(±2.17)	42.53(±3.27)[7]	42.33(±3.33)[10]
95% Confidence Interval	-2.441 to -0.6419	-2.303 to -0.4189	-2.437 to 1.013	-2.746 to 0.6638
P value (Difference between Mean Hylam &Mean British)	**0.0011**	**0.0054**	**0.4120**	**0.2265**
Indian Mean(±SD)	5.54(±1.95)[2]	5.78(±1.98)[4]	39.49(±3.20)	39.71(±3.08)
British Mean(±SD)	6.07(±1.70)[2]	6.22(±2.17)[4]	42.53(±3.27)	42.33(±3.33)
95% Confidence Interval	-0.4161 to 1.476	-0.6337 to 1.513	1.369 to 4.712	0.9634 to 4.278
P value (Difference between Mean Indian &Mean British)	**0.2667**	**0.4155**	**0.0006**	**0.0025**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 104: Inter-Population Comparisons of :(D2H R & D2H L)

(a) The distance (horizontal) from the infraorbital foramen to the supraorbital foramen: right side [D2H R].

(b) The distance (horizontal) from the infraorbital foramen to the supraorbital foramen: left side [D2H L].

	D2H R	D2H L
Hokien Mean(±SD)	-3.61(±3.80)[1]	-3.57(±3.21)[7]
Hylam Mean(±SD)	-2.79(±3.20)[1]	-2.37(±3.75)[7]
95% Confidence Interval	-1.002 to 2.628	-0.6057 to 3.003
P value (Difference between Mean Hokien &Mean Hylam)	**0.3735**	**0.1888**
Hokien Mean(±SD)	-3.35(±3.50)[2]	-2.97(±4.01)[8]
Indian Mean(±SD)	-3.35(±3.50)[2]	-2.97(±4.01)[8]
95% Confidence Interval	-1.628 to 2.145	-1.277 to 2.479
P value (Difference between Mean Hokien &Mean Indian)	**0.7848**	**0.5242**
Hokien Mean(±SD)	-3.35(±3.50)[3]	-2.97(±4.01)[9]
British Mean(±SD)	-2.78(±3.82)[3]	-3.86(±3.86)[9]
95% Confidence Interval	-1.143 to 2.795	-2.126 to 1.547
P value (Difference between Mean Hokien &Mean British)	**0.4045**	**0.7536**
Hylam Mean(±SD)	-2.79(±3.20)[4]	-2.37(±3.75)[10]
Indian Mean(±SD)	-3.35(±3.50)[4]	-2.97(±4.01)[10]
95% Confidence Interval	-2.287 to 1.178	-2.603 to 1.408
P value (Difference between Mean Hylam &Mean Indian)	**0.5242**	**0.5532**
Hylam Mean(±SD)	-2.79(±3.20)[5]	-2.37(±3.75)[11]
British Mean(±SD)	-2.78(±3.82)[5]	-3.86(±3.86)[11]
95% Confidence Interval	-1.809 to 1.835	-3.456 to 0.4793
P value (Difference between Mean Hylam &Mean British)	**0.9887**	**0.1354**
Indian Mean(±SD)	-3.35(±3.50)[6]	-2.97(±4.01)[12]
British Mean(±SD)	-2.78(±3.82)[6]	-3.86(±3.86)[12]
95% Confidence Interval	-1.326 to 2.461	-2.926 to 1.145
P value (Difference between Mean Indian &Mean British)	**0.5508**	**0.3847**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.2.3 Distances Related to Mental Foramen

Table 105: Inter-Population Comparisons of :(D3A R & D3A L)

(a) The distance from the mental foramen to the symphysis menti: right side [D3A R].

(b) The distance from the mental foramen to the symphysis menti: left side [D3A L].

	D3A R	D3A L
Hokien Mean(±SD)	26.04(± 1.78)[1]	26.09(± 1.55)[6]
Hylam Mean(±SD)	26.52(± 2.01)[1]	26.78(± 2.02)[6]
95% Confidence Interval	-0.5017 to 1.462	-0.2395 to 1.620
P value (Difference between Mean Hokien &Mean Hylam)	**0.3318**	**0.1427**
Hokien Mean(±SD)	26.04(± 1.78)[2]	26.09(± 1.55)[7]
Indian Mean(±SD)	25.58(± 1.84)[2]	25.50(± 1.45)[7]
95% Confidence Interval	-1.401 to 0.4739	-1.365 to 0.1820
P value (Difference between Mean Hokien &Mean Indian)	**0.3263**	**0.1312**
Hokien Mean(±SD)	26.04(± 1.78)[3]	26.09(± 1.55)[8]
British Mean(±SD)	25.16(± 2.39)[3]	25.55(± 2.57)[8]
95% Confidence Interval	-1.968 to 0.2115	-1.633 to 0.5595
P value (Difference between Mean Hokien &Mean British)	**0.1121**	**0.3312**
Hylam Mean(±SD)	26.52(± 2.01)[4]	26.78(± 2.02)
Indian Mean(±SD)	25.58(± 1.84)[4]	25.50(± 1.45)
95% Confidence Interval	-1.940 to 0.05239	-2.190 to -0.3733
P value (Difference between Mean Hylam &Mean Indian)	**0.0629**	**0.0065**
Hylam Mean(±SD)	26.52(± 2.01)	26.78(± 2.02)
British Mean(±SD)	25.16(± 2.39)	25.55(± 2.57)
95% Confidence Interval	-2.498 to -0.2177	-2.422 to -0.03156
P value (Difference between Mean Hylam &Mean British)	**0.0204**	**0.0444**
Indian Mean(±SD)	25.58(± 1.84)[5]	25.50(± 1.45)[9]
British Mean(±SD)	25.16(± 2.39)[5]	25.55(± 2.57)[9]
95% Confidence Interval	-1.517 to 0.6882	-1.023 to 1.133
P value (Difference between Mean Indian &Mean British)	**0.4549**	**0.9190**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 106: Inter-Population Comparisons of :(D3B R & D3B L)

(a) The distance from the mental foramen to the posterior border of the mandible: right side [D3B R].

(b) The distance from the mental foramen to the posterior border of the mandible: left side [D3B L].

	D3B R	D3B L
Hokien Mean(±SD)	69.73(± 4.40)	70.22(±3.77)[3]
Hylam Mean(±SD)	72.57(± 4.50)	71.98(±4.44)[3]
95% Confidence Interval	0.5438 to 5.148	-0.3660 to 3.893
P value (Difference between Mean Hokien &Mean Hylam)	**0.0163**	**0.1028**
Hokien Mean(±SD)	69.73(± 4.40)[1]	70.22(±3.77)[4]
Indian Mean(±SD)	69.55(± 4.11)[1]	69.49(±4.15)[4]
95% Confidence Interval	-2.381 to 2.020	-2.780 to 1.319
P value (Difference between Mean Hokien &Mean Indian)	**0.8700**	**0.4785**
Hokien Mean(±SD)	69.73(± 4.40)	70.22(±3.77)
British Mean(±SD)	72.68(± 5.24)	72.79(±5.33)
95% Confidence Interval	0.4537 to 5.454	0.1802 to 4.950
P value (Difference between Mean Hokien &Mean British)	**0.0214**	**0.0355**
Hylam Mean(±SD)	72.57(± 4.50)	71.98(±4.44)
Indian Mean(±SD)	69.55(± 4.11)	69.49(±4.15)
95% Confidence Interval	-5.255 to -0.7981	-4.716 to -0.2716
P value (Difference between Mean Hylam &Mean Indian)	**0.0086**	**0.0285**
Hylam Mean(±SD)	72.57(± 4.50)[2]	71.98(±4.44)[5]
British Mean(±SD)	72.68(± 5.24)[2]	72.79(±5.33)[5]
95% Confidence Interval	-2.416 to 2.633	-1.733 to 3.337
P value (Difference between Mean Hylam &Mean British)	**0.9318**	**0.5290**
Indian Mean(±SD)	69.55(± 4.11)	69.49(±4.15)
British Mean(±SD)	72.68(± 5.24)	72.79(±5.33)
95% Confidence Interval	0.7020 to 5.567	0.8274 to 5.764
P value (Difference between Mean Indian &Mean British)	**0.0125**	**0.0098**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 107: Inter-Population Comparisons of: (D3C R & D3C L)

(a) The distance from the mental foramen to the inferior border of the mandible: right side [D3C R].

(b) The distance from the mental foramen to the inferior border of the mandible: left side [D3C L].

	D3C R	D3C L
Hokien Mean(±SD)	15.05 (± 1.49)[1]	14.75 (± 1.56)
Hylam Mean(±SD)	15.76 (± 1.46)[1]	15.57 (± 1.28)
95% Confidence Interval	-0.05208 to 1.470	0.08254 to 1.557
P value (Difference between Mean Hokien &Mean Hylam)	**0.0673**	**0.0299**
Hokien Mean(±SD)	15.05 (± 1.49)	14.75 (± 1.56)
Indian Mean(±SD)	14.06 (± 1.70)	13.86 (± 1.50)
95% Confidence Interval	-1.822 to -0.1732	-1.683 to -0.09813
P value (Difference between Mean Hokien &Mean Indian)	**0.0186**	**0.0283**
Hokien Mean(±SD)	15.05 (± 1.49)[2]	14.75 (± 1.56)[4]
British Mean(±SD)	14.40 (± 1.49)[2]	14.09 (± 1.35)[4]
95% Confidence Interval	-1.426 to 0.1096	-1.410 to 0.09935
P value (Difference between Mean Hokien &Mean British)	**0.0915**	**0.0875**
Hylam Mean(±SD)	15.76 (± 1.46)	15.57 (± 1.28)
Indian Mean(±SD)	14.06 (± 1.70)	13.86 (± 1.50)
95% Confidence Interval	-2.524 to -0.8883	-2.431 to -0.9901
P value (Difference between Mean Hylam &Mean Indian)	**0.0001**	**< 0.0001**
Hylam Mean(±SD)	15.76 (± 1.46)	15.57 (± 1.28)
British Mean(±SD)	14.40 (± 1.49)	14.09 (± 1.35)
95% Confidence Interval	-2.128 to -0.6059	-2.154 to -0.7966
P value (Difference between Mean Hylam &Mean British)	**0.0007**	**< 0.0001**
Indian Mean(±SD)	14.06 (± 1.70)[3]	13.86 (± 1.50)[5]
British Mean(±SD)	14.40 (± 1.49)[3]	14.09 (± 1.35)[5]
95% Confidence Interval	-0.4848 to 1.163	-0.5028 to 0.9728
P value (Difference between Mean Indian &Mean British)	**0.4132**	**0.5263**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.2.2.4 Distances Related to Mandibular Foramen

Table 108: Inter-Population Comparisons of: (D4A R, D4A L, D4B R & D4B L)

(a) The distance from the mandibular foramen to the inferior border of the mandible: right side [D4A R].

(b) The distance from the mandibular foramen to the inferior border of the mandible: left side [D4A L].

(c) The distance from the mandibular foramen to mandibular notch: right side [D4B R].

(d) The distance from the mandibular foramen to the mandibular notch: left side [D4B L].

	D4A R	D4A L	D4B R	D4B L
Hokien Mean(±SD)	23.70(±3.58)[1]	22.96(±3.48)[6]	24.81(±3.37)[12]	24.28(±3.19)[18]
Hylam Mean(±SD)	23.00(±3.39)[1]	22.36(±3.42)[6]	24.09(±3.56)[12]	23.48(±3.68)[18]
95% Confidence Interval	-2.505 to 1.098	-1.652 to 1.961	-2.504 to 1.079	-2.577 to 0.9821
P value (Difference between Mean Hokien &Mean Hylam)	**0.4377**	**0.8648**	**0.4291**	**0.3734**
Hokien Mean(±SD)	23.70(±3.58)	22.96(±3.48)[7]	24.81(±3.37)[13]	24.28(±3.19)[19]
Indian Mean(±SD)	21.48(±3.90)	20.88(±4.06)[7]	23.92(±3.97)[13]	23.47(±3.30)[19]
95% Confidence Interval	-4.159 to -0.2893	-3.296 to 0.6565	-2.785 to 1.019	-2.484 to 0.8680
P value (Difference between Mean Hokien &Mean Indian)	**0.0250**	**0.1865**	**0.3564**	**0.3385**
Hokien Mean(±SD)	23.70(±3.58)[2]	22.96(±3.48)[8]	24.81(±3.37)[14]	24.28(±3.19)[20]
British Mean(±SD)	22.55(±3.79)[2]	21.75(±4.04)[8]	25.86(±3.72)[14]	25.79(±2.95)[20]
95% Confidence Interval	-3.058 to 0.7516	-2.418 to 1.521	-0.7836 to 2.887	-0.07718 to 3.095
P value (Difference between Mean Hokien &Mean British)	**0.2305**	**0.6501**	**0.2561**	**0.0618**
Hylam Mean(±SD)	23.00(±3.39)[3]	22.36(±3.42)[9]	24.09(±3.56)[15]	23.48(±3.68)[21]
Indian Mean(±SD)	21.48(±3.90)[3]	20.88(±4.06)[9]	23.92(±3.97)[15]	23.47(±3.30)[21]
95% Confidence Interval	-3.410 to 0.3686	-3.415 to 0.4667	-2.119 to 1.777	-1.818 to 1.797
P value (Difference between Mean Hylam &Mean Indian)	**0.1126**	**0.1338**	**0.8614**	**0.9909**
Hylam Mean(±SD)	23.00(±3.39)[4]	22.36(±3.42)[10]	24.09(±3.56)[16]	23.48(±3.68)
British Mean(±SD)	22.55(±3.79)[4]	21.75(±4.04)[10]	25.86(±3.72)[16]	25.79(±2.95)
95% Confidence Interval	-2.308 to 1.409	-2.537 to 1.331	-0.1187 to 3.647	0.5822 to 4.031
P value (Difference between Mean Hylam &Mean British)	**0.6298**	**0.5350**	**0.0658**	**0.0096**
Indian Mean(±SD)	21.48(±3.90)[5]	20.88(±4.06)[11]	23.92(±3.97)[17]	23.47(±3.30)
British Mean(±SD)	22.55(±3.79)[5]	21.75(±4.04)[11]	25.86(±3.72)[17]	25.79(±2.95)
95% Confidence Interval	-0.9170 to 3.059	-1.222 to 2.965	-0.05332 to 3.923	0.6999 to 3.934
P value (Difference between Mean Indian &Mean British)	**0.2853**	**0.4082**	**0.0563**	**0.0057**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 109: Inter-Population Comparisons of: (D4C R, D4C L, D4D R & D4D L)

(a) The distance from the mandibular foramen to the posterior border of the ramus at the same level: right side [D4C R].

(b) The distance from the mandibular foramen to the posterior border of the ramus at the same level: left side [D4C L].

(c) The distance from the mandibular foramen to the posterior border of the ramus at the level of the occlusal line: right side [D4D R].

(d) The distance from the mandibular foramen to the posterior border of the ramus at the level of the occlusal line: left side [D4D L].

	D4C R	D4C L	D4D R	D4D L
Hokien Mean(±SD)	16.45(±1.99)[1]	16.44(±1.91)[3]	16.50(±2.44)[5]	16.15(±2.41)[9]
Hylam Mean(±SD)	16.93(±2.17)[1]	16.40(±1.90)[3]	16.94(±2.54)[5]	16.29(±2.13)[9]
95% Confidence Interval	-0.5922 to 1.559	-1.025 to 0.9408	-0.8368 to 1.733	-1.033 to 1.320
P value (Difference between Mean Hokien &Mean Hylam)	**0.3721**	**0.9316**	**0.4878**	**0.8078**
Hokien Mean(±SD)	16.45(±1.99)	16.44(±1.91)	16.50(±2.44)	16.15(±2.41)
Indian Mean(±SD)	14.78(±2.25)	15.04(±2.64)	14.36(±2.33)	14.74(±2.91)
95% Confidence Interval	-2.766 to -0.5711	-2.586 to -0.2064	-3.367 to -0.9018	-2.785 to -0.02292
P value (Difference between Mean Hokien &Mean Indian)	**0.0035**	**0.0222**	**0.0010**	**0.0464**
Hokien Mean(±SD)	16.45(±1.99)	16.44(±1.91)	16.50(±2.44)[6]	16.15(±2.41)[10]
British Mean(±SD)	14.65(±2.52)	14.63(±2.42)	15.47(±3.25)[6]	14.98(±2.56)[10]
95% Confidence Interval	-2.979 to -0.6173	-2.936 to -0.6843	-2.510 to 0.4571	-2.448 to 0.1230
P value (Difference between Mean Hokien &Mean British)	**0.0035**	**0.0021**	**0.1714**	**0.0754**
Hylam Mean(±SD)	16.93(±2.17)	16.40(±1.90)	16.94(±2.54)	16.29(±2.13)
Indian Mean(±SD)	14.78(±2.25)	15.04(±2.64)	14.36(±2.33)	14.74(±2.91)
95% Confidence Interval	-3.294 to -1.010	-2.541 to -0.1670	-3.841 to -1.324	-2.865 to -0.2301
P value (Difference between Mean Hylam &Mean Indian)	**0.0004**	**0.0261**	**0.0001**	**0.0221**
Hylam Mean(±SD)	16.93(±2.17)	16.40(±1.90)	16.94(±2.54)[7]	16.29(±2.13)
British Mean(±SD)	14.65(±2.52)	14.63(±2.42)	15.47(±3.25)[7]	14.98(±2.56)
95% Confidence Interval	-3.506 to -1.058	-2.890 to -0.6449	-2.980 to 0.03055	-2.523 to -0.08913
P value (Difference between Mean Hylam &Mean British)	**0.0004**	**0.0026**	**0.0547**	**0.0359**
Indian Mean(±SD)	14.78(±2.25)[2]	15.04(±2.64)[4]	14.36(±2.33)[8]	14.74(±2.91)[11]
British Mean(±SD)	14.65(±2.52)[2]	14.63(±2.42)[4]	15.47(±3.25)[8]	14.98(±2.56)[11]
95% Confidence Interval	-1.374 to 1.114	-1.721 to 0.8936	-0.3529 to 2.568	-1.174 to 1.656
P value (Difference between Mean Indian &Mean British)	**0.8354**	**0.5288**	**0.1344**	**0.7343**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 110: Inter-Population Comparisons of: (D4E R, D4E L, D4F R & D4F L)

(a) The distance from the mandibular foramen to the internal oblique ridge at the level of the occlusal line: right side [D4E R].

(b) The distance from the mandibular foramen to the internal oblique ridge at the level of the occlusal line: left side [D4E L].

(c) The distance from the mandibular foramen to the occlusal line: right side [D4F R].

(d) The distance from the mandibular foramen to the occlusal line: left side [D4F L].

	D4E R	D4E L	D4F R	D4F L
Hokien Mean(±SD)	14.63(±2.04)[1]	14.96(±2.45)[6]	-2.53(±3.72)[9]	-2.44(±3.09)[15]
Hylam Mean(±SD)	15.23(±2.06)[1]	15.34(±2.12)[6]	-2.96(±4.91)[9]	-2.12(±3.12)[15]
95% Confidence Interval	-0.4586 to 1.657	-0.8062 to 1.564	-2.681 to 1.822	-1.286 to 1.923
P value (Difference between Mean Hokien &Mean Hylam)	**0.2616**	**0.5246**	**0.7038**	**0.6924**
Hokien Mean(±SD)	14.63(±2.04)[2]	14.96(±2.45)	-2.53(±3.72)[10]	-2.44(±3.09)[16]
Indian Mean(±SD)	13.68(±1.99)[2]	13.54(±2.25)	-1.54(±3.61)[10]	-2.04(±3.57)[16]
95% Confidence Interval	-1.991 to 0.09106	-2.637 to -0.2040	-0.9091 to 2.881	-1.328 to 2.123
P value (Difference between Mean Hokien &Mean Indian)	**0.0729**	**0.0229**	**0.3020**	**0.6464**
Hokien Mean(±SD)	14.63(±2.04)[3]	14.96(±2.45)[7]	-2.53(±3.72)[11]	-2.44(±3.09)[17]
British Mean(±SD)	14.86(±2.54)[3]	14.76(±1.80)[7]	-3.24(±3.72)[11]	-3.14(±3.45)[17]
95% Confidence Interval	-0.9642 to 1.416	-1.309 to 0.9131	-2.638 to 1.207	-2.394 to 0.9932
P value (Difference between Mean Hokien &Mean British)	**0.7051**	**0.7224**	**0.4590**	**0.4112**
Hylam Mean(±SD)	15.23(±2.06)	15.34(±2.12)	-2.96(±4.91)[12]	-2.12(±3.12)[18]
Indian Mean(±SD)	13.68(±1.99)	13.54(±2.25)	-1.54(±3.61)[12]	-2.04(±3.57)[18]
95% Confidence Interval	-2.595 to -0.5036	-2.931 to -0.6679	-0.8108 to 3.642	-1.653 to 1.811
P value (Difference between Mean Hylam &Mean Indian)	**0.0044**	**0.0023**	**0.2082**	**0.9277**
Hylam Mean(±SD)	15.23(±2.06)[4]	15.34(±2.12)[8]	-2.96(±4.91)[13]	-2.12(±3.12)[19]
British Mean(±SD)	14.86(±2.54)[4]	14.76(±1.80)[8]	-3.24(±3.72)[13]	-3.14(±3.45)[19]
95% Confidence Interval	-1.567 to 0.8213	-1.595 to 0.4405	-2.536 to 1.964	-2.719 to 0.6813
P value (Difference between Mean Hylam &Mean British)	**0.5344**	**0.2609**	**0.7999**	**0.2352**
Indian Mean(±SD)	13.68(±1.99)[5]	13.54(±2.25)	-1.54(±3.61)[14]	-2.04(±3.57)[20]
British Mean(±SD)	14.86(±2.54)[5]	14.76(±1.80)	-3.24(±3.72)[14]	-3.14(±3.45)[20]
95% Confidence Interval	-0.003302 to 2.356	0.1684 to 2.276	-3.595 to 0.1915	-2.913 to 0.7170
P value (Difference between Mean Indian &Mean British)	**0.0506**	**0.0238**	**0.0772**	**0.2308**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

Table 111: Inter-Population Comparisons of: (D4G R, D4G L, D4H R & D4H L)

(a) The distance from the posterior border of the ramus to the internal oblique ridge at the level of the occlusal line: right side [D4G R].

(b) The distance from the posterior border of the ramus to the internal oblique ridge at the level of the occlusal line: left side [D4G L].

(c) The distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line: right side [D4H R].

(d) The distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line: left side [D4H L].

	D4G R	D4G L	D4H R	D4H L
Hokien Mean(±SD)	29.90(±2.83)[1]	30.29(±3.09)[4]	34.33(±2.85)[5]	34.92(±3.91)[7]
Hylam Mean(±SD)	30.69(±2.86)[1]	30.45(±2.69)[4]	34.32(±2.70)[5]	34.34(±2.40)[7]
95% Confidence Interval	-0.6852 to 2.258	-1.340 to 1.655	-1.516 to 1.494	-1.956 to 0.7973
P value (Difference between Mean Hokien &Mean Hylam)	**0.2892**	**0.8338**	**0.9880**	**0.4029**
Hokien Mean(±SD)	29.90(±2.83)	30.29(±3.09)	34.33(±2.85)	34.92(±3.91)
Indian Mean(±SD)	27.31(±2.53)	26.99(±3.04)	31.90(±2.77)	31.71(±2.90)
95% Confidence Interval	-3.980 to -1.204	-4.890 to -1.723	-3.883 to -0.9777	-4.710 to -1.710
P value (Difference between Mean Hokien &Mean Indian)	**0.0004**	**< 0.0001**	**0.0014**	**< 0.0001**
Hokien Mean(±SD)	29.90(±2.83)[2]	30.29(±3.09)	34.33(±2.85)	34.92(±3.91)
British Mean(±SD)	28.68(±3.04)[2]	28.60(±2.83)	32.46(±3.47)	32.05(±3.69)
95% Confidence Interval	-2.741 to 0.2943	-3.226 to -0.1604	-3.513 to -0.2296	-4.589 to -1.159
P value (Difference between Mean Hokien &Mean British)	**0.1121**	**0.0310**	**0.0262**	**0.0014**
Hylam Mean(±SD)	30.69(±2.86)	30.45(±2.69)	34.32(±2.70)	34.34(±2.40)
Indian Mean(±SD)	27.31(±2.53)	26.99(±3.04)	31.90(±2.77)	31.71(±2.90)
95% Confidence Interval	-4.775 to -1.981	-4.947 to -1.981	-3.903 to -0.9354	-4.005 to -1.256
P value (Difference between Mean Hylam &Mean Indian)	**< 0.0001**	**< 0.0001**	**0.0018**	**0.0003**
Hylam Mean(±SD)	30.69(±2.86)	30.45(±2.69)	34.32(±2.70)	34.34(±2.40)
British Mean(±SD)	28.68(±3.04)	28.60(±2.83)	32.46(±3.47)	32.05(±3.69)
95% Confidence Interval	-3.536 to -0.4838	-3.279 to -0.4224	-3.529 to -0.1908	-3.901 to -0.6880
P value (Difference between Mean Hylam &Mean British)	**0.0107**	**0.0120**	**0.0296**	**0.0059**
Indian Mean(±SD)	27.31(±2.53)[3]	26.99(±3.04)	31.90(±2.77)[6]	31.71(±2.90)[8]
British Mean(±SD)	28.68(±3.04)[3]	28.60(±2.83)	32.46(±3.47)[6]	32.05(±3.69)[8]
95% Confidence Interval	-0.07738 to 2.814	0.09510 to 3.132	-1.063 to 2.181	-1.377 to 2.049
P value (Difference between Mean Indian &Mean British)	**0.0631**	**0.0377**	**0.4929**	**0.6959**

Same superscript numbers in each vertical column (right or left side) indicate no significant difference between populations. Unpaired t test at $\alpha = 0.05$; ($P > 0.05$).

8.3 Results of the Comparisons between Electronic digital and 3D Laser Scanning Measurements of Ipsilateral Distances Related to Four Foramina in each of the Four Population

In this section, the comparisons of ipsilateral distances related to supraorbital, infraorbital, mental and mandibular foramen regions in each of the four populations are given. Statistical analysis was performed using Bland-Altman Plot.

Two representative Bland-Altman plots are shown; the remaining plots for each table are available in the appendix.

Summary: Mostly good agreement between the electronic calliper and the scanning measurements was obtained for measurements in each of the four population groups relating to the all distances related to the four foramina except that there were a very few low or very low agreements between, the most medial point of the supraorbital foramen and the temporal crest, the mandibular foramen to inferior border of the mandible and the mandibular foramen to posterior border of the ramus at occlusal line.

8.3.1 Ipsilateral Distances Related to Supraorbital Foramen in Each Population

(a) Right Supraorbital to Left Supraorbital Foramina: [D1A]

(b) Supraorbital Foramen to Midline: Right [D1B R] & Left Side [D1B L]

(c) Supraorbital Foramen to Temporal Crest: Right [D1C R] & Left Side [D1C L]

(d) Right to Left Fronto-Maxillary Sutures: Distance [D1E]

a. Right to Left Supraorbital Foramina: Distance D1A

Figure 41: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1A (Hokien)

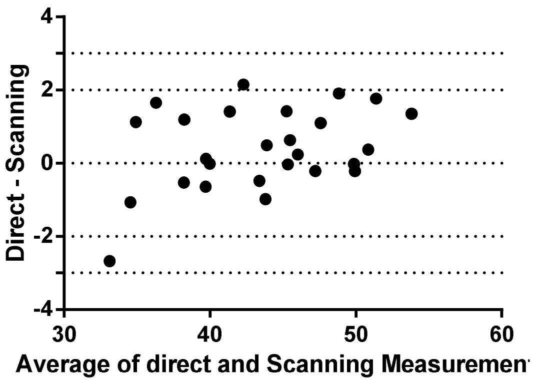


Figure 42: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1A (Hylam)

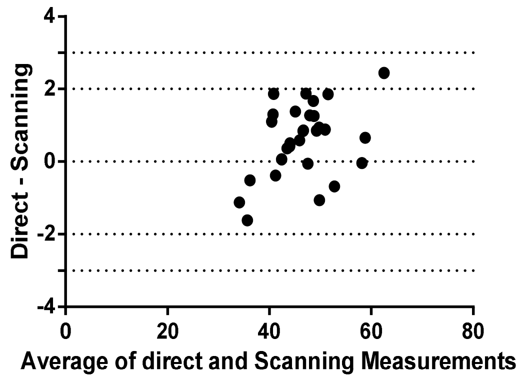


Figure 41 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D1A in the Hokien population. Most measurements were found between "-1.8 to 2.57" in either direction of the mean. [All measurements in mm.]

Figure 42 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D1A in the Hylam population. Most measurements were found between "-1.35 to 2.56" in either direction of the mean. [All measurements in mm.]

Table 112: Descriptive Statistics Related to Distance D1A in the Four Populations

Population	Result	D1A
Hokien	Bias	0.3841
	SD of bias	1.115
	95% Limits of agreement	-1.801 to 2.569
Hylam	Bias	0.6053
	SD of bias	0.9952
	95% Limits of agreement	-1.345 to 2.556
Indian	Bias	0.9270
	SD of bias	0.8733
	95% Limits of agreement	-0.7847 to 2.639
British	Bias	1.152
	SD of bias	1.126
	95% Limits of agreement	-1.055 to 3.359

Results: Table 112 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D1A in all populations. All measurements were found between “-1.80 to 3.36” in either direction. The bias (the average difference between the electronic calliper and scanning measurements for appropriate distance) indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.15 mm.

b. Supraorbital Foramen to Midline: Right D1B R & Left Side D1B L

Figure 43: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1B R (Hokien)

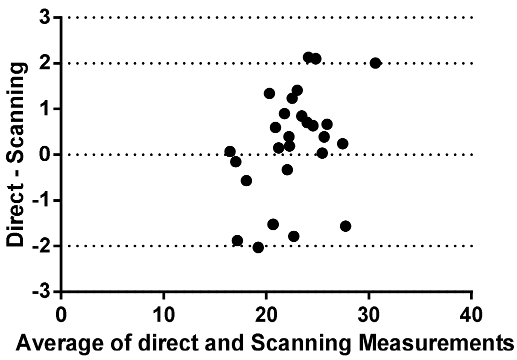


Figure 44: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1B L (Hokien)

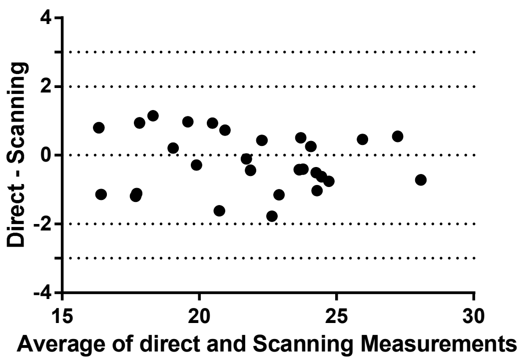


Figure 43 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D1B R in the Hokien population. Most measurements were found between “-2.09 to 2.56” in either direction of the mean. [All measurements in mm.]

Figure 44 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D1B L in the Hokien population. Most measurements were found between “-1.87 to 1.49” in either direction of the mean. [All measurements in mm.]

Table 113: Descriptive Statistics Related to Distance D1B R & D1B L in the Four Populations

Population	Result	D1B R	D1B L
Hokien	Bias	0.2317	-0.1885
	SD of bias	1.186	0.8553
	95% Limits of agreement	-2.093 to 2.557	-1.865 to 1.488
Hylam	Bias	0.4968	0.4951
	SD of bias	0.8316	0.9047
	95% Limits of agreement	-1.133 to 2.127	-1.278 to 2.268
Indian	Bias	0.5590	0.1096
	SD of bias	0.8596	0.9873
	95% Limits of agreement	-1.126 to 2.244	-1.826 to 2.045
British	Bias	1.009	0.7318
	SD of bias	1.095	0.8427
	95% Limits of agreement	-1.136 to 3.155	- 0.9199 to 2.384

Result: Table 113 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D1B R and D1B L in all populations. All measurements were found between "-2.09 to 3.16" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.01 mm.

c. Supraorbital Foramen to Temporal Crest: Right [D1C R] & Left Side [D1C L]

Figure 45: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1C R (Hylam)

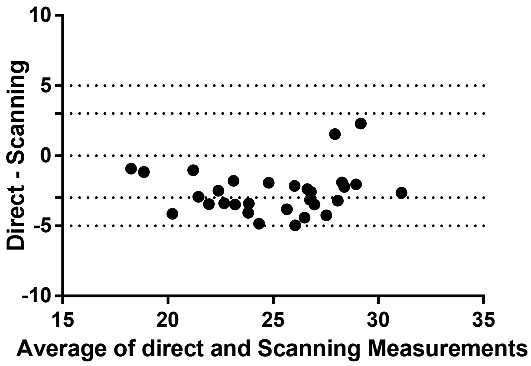


Figure 46: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1C L (Hylam)

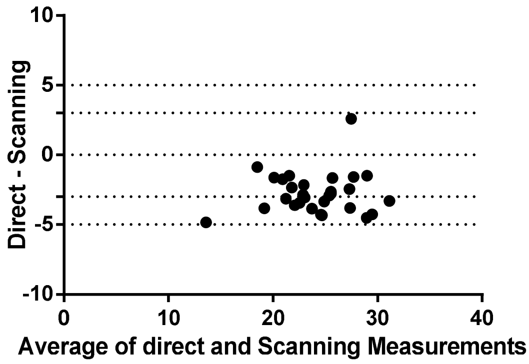


Figure 45 shows Bland-Altman plots with low agreements between electronic calliper (Direct) and scanning measurements with regard to D1C R in the Hylam population. Most measurements were found between (-5.81 to 0.6) in a negative direction of the mean. [All measurements in mm.]

Figure 46 shows Bland-Altman plots with low agreements between electronic calliper (Direct) and scanning measurements with regard to D1C L in the Hylam population. Most measurements were found between "-5.63 to 0.14" in a negative direction of the mean. [All measurements in mm.]

Table 114: Descriptive Statistics Related to Distance D1C R & D1C L in the Four Populations

Population	Result	D1C R	D1C L
Hokien	Bias	-1.435	-2.516
	SD of bias	1.757	1.143
	95% Limits of agreement	-4.879 to2.009	-4.755 to -0.2758
Hylam	Bias	-2.609	-2.745
	SD of bias	1.635	1.474
	95% Limits of agreement	-5.813 to 0.5952	-5.634 to 0.1449
Indian	Bias	-2.187	-2.596
	SD of bias	1.434	1.474
	95% Limits of agreement	-4.998 to 0.6229	--5.485 to 0.2921
British	Bias	-2.606	-2.729
	SD of bias	1.420	1.372
	95% Limits of agreement	-5.389 to 0.1777	-5.418 to -0.04092

Result: Table 114 shows that there were overall low agreements between electronic calliper and scanning measurements with regard to D1C R and D1C L in all populations. All measurements were found between "-5.63 to 2.01" in either direction. The bias indicates that the electronic calliper measurements were smaller than the scanning measurements with a maximum of -2.745 mm.

d. Right to Left Fronto-Maxillary Sutures: Distance D1E

Figure 47: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1E (Indian)

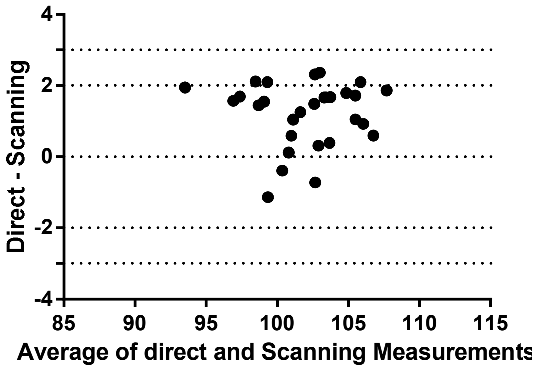


Figure 48: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D1E (British)

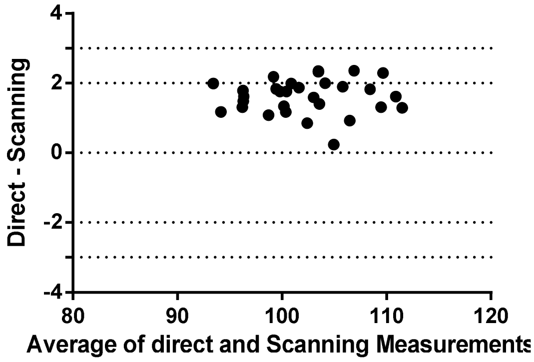


Figure 47 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D1E in the Indian population. Most measurements were found between "-0.54 to 3.01" in a positive direction of the mean. [All measurements in mm.]

Figure 48 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D1E in the British population. Most measurements were found between "0.65 to 2.59" in a positive direction of the mean. [All measurements in mm.]

Table 115: Descriptive Statistics Related to Distance D1E in the Four Populations

Population	Result	D1E
Hokien	Bias	1.654
	SD of bias	0.4513
	95% Limits of agreement	0.7698 to 2.539
Hylam	Bias	1.182
	SD of bias	0.7569
	95% Limits of agreement	-0.3019 to 2.665
Indian	Bias	1.234
	SD of bias	0.9027
	95% Limits of agreement	-0.5357 to 3.003
British	Bias	1.620
	SD of bias	0.4969
	95% Limits of agreement	0.6457 to 2.594

Results: Table 115 shows that there were overall very low agreements between electronic calliper and scanning measurements with regard to D1E in all populations.

All measurements were found between “-0.54 to 3.01” in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.65 mm.

8.3.2 Ipsilateral Distances Related to Infraorbital Foramen in Each Population

(a) Right Infraorbital to Left Infraorbital Foramina: Distance D2A

(b) Infraorbital Foramen to Midline at the Level of the Supraorbital Foramen: Right [D2B R] & Left Side [D2B L]

(c) Infraorbital Foramen to Anterior Nasal Spine: Right [D2C R] & Left Side [D2C L]

(d) Infraorbital Foramen to Infraorbital Rim: Right [D2F R] & Left Side [D2F L]

(e) Infraorbital to Supraorbital Foramen (Vertically): Right [D2G R] & Left Side [D2G L]

a. Right to Left Infraorbital Foramina: Distance D2A

Figure 49: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2A (Hokien)

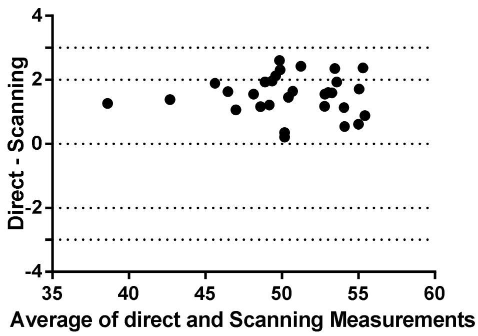


Figure 50: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2A (Hylam)

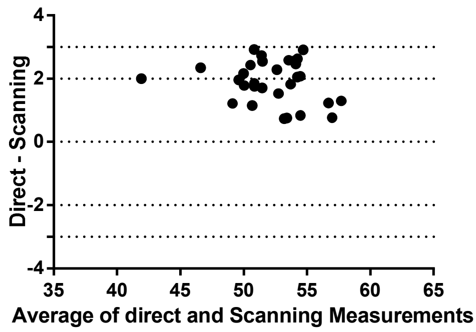


Figure 49 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D2A in the Hokien population. Most measurements were found between “0.3 to 2.74” in a positive direction of the mean. [All measurements in mm.]

Figure 50 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D2A in the Hylam population. Most measurements were found between “0.6 to 3.21” in a positive direction of the mean. [All measurements in mm.]

Table 116: Descriptive Statistics Related to Distance D2A in the Four Populations

Population	Results	D2A
Hokien	Bias	1.521
	SD of bias	0.6217
	95% Limits of agreement	0.3027 to 2.740
Hylam	Bias	1.905
	SD of bias	0.6663
	95% Limits of agreement	0.5991 to 3.211
Indian	Bias	2.152
	SD of bias	0.7586
	95% Limits of agreement	0.6651 to 3.639
British	Bias	1.974
	SD of bias	1.015
	95% Limits of agreement	-0.01522 to 3.963

Results: Table 116 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D2A in all populations. All measurements were found between “-0.02 to 3.96” in a positive direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 2.15 mm.

b. Infraorbital Foramen to Midline at the Level of the Supraorbital Foramen: Right [D2B R] & Left Side [D2B L]

Figure 51: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2B R (Indian)

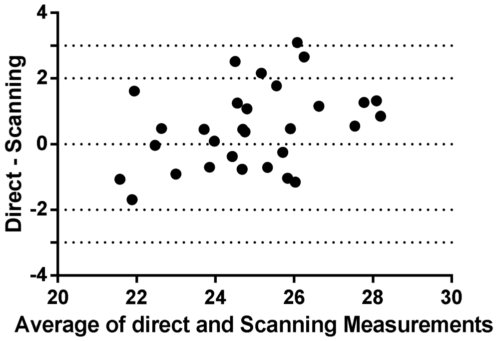


Figure 52: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2B L (Indian)

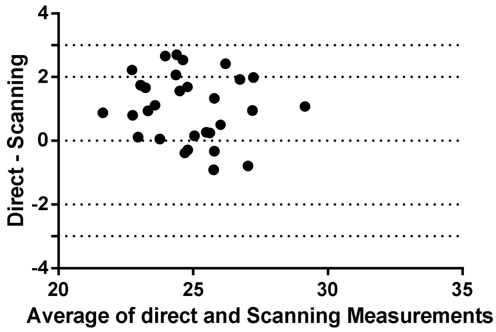


Figure 51: shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2B R in the Indian population. Most measurements were found between "- 1.9 to 2.9" in either direction of the mean. [All measurements in mm.]

Figure 52 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D2B L in the Indian population. Most measurements were found between "- 1.04 to 3.1" in either direction of the mean. [All measurements in mm.]

Table 117: Descriptive Statistics Related to Distance D2B R & D2B L in the Four Populations

Population	Results	D2B R	D2B L
Hokien	Bias	-0.1302	0.5716
	SD of bias	1.126	1.111
	95% Limits of agreement	-2.338 to 2.077	-1.605 to 2.748
Hylam	Bias	-0.001100	0.7429
	SD of bias	1.224	1.220
	95% Limits of agreement	-2.401 to 2.399	-1.649 to 3.135
Indian	Bias	0.4967	1.031
	SD of bias	1.239	1.056
	95% Limits of agreement	-1.931 to 2.924	-1.040 to 3.101
British	Bias	0.4298	0.9563
	SD of bias	1.258	1.095
	95% Limits of agreement	-2.037 to 2.896	-1.190 to 3.103

Results: Table 117 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D2B R and D2B L in all populations. All measurements were found between "-0.02 to 3.96" in a positive direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.65 mm.

c. Infraorbital Foramen to Anterior Nasal Spine: Right [D2C R] & Left Side [D2C L]

Figure 53: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2C R (British)

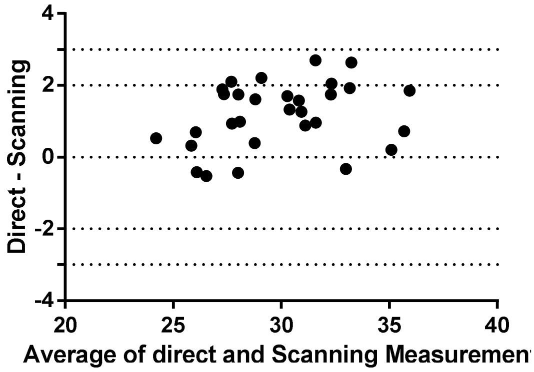


Figure 54: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2C L (British)

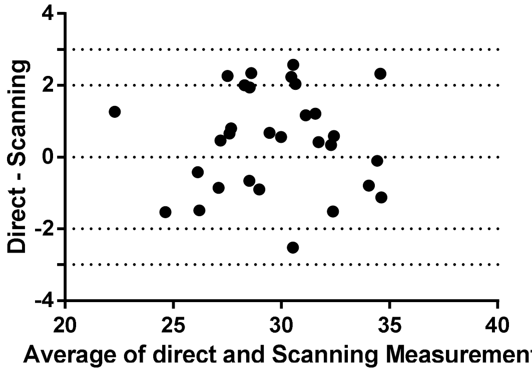


Figure 53 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2C R in the British population. Most measurements were found between "-0.6 to 2.95" in a positive direction of the mean. [All measurements in mm.]

Figure 54 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2C L in the British population. Most measurements were found between "- 2.3 to 3.2" in a positive direction of the mean. [All measurements in mm.]

Table 118: Descriptive Statistics Related to Distance D2C R & D2C L in the Four Populations

Population	Results	D2C R	D2C L
Hokien	Bias	0.4023	0.3031
	SD of bias	1.135	1.579
	95% Limits of agreement	-1.822 to 2.627	-2.793 to 3.399
Hylam	Bias	1.039	0.4967
	SD of bias	1.271	1.231
	95% Limits of agreement	-1.453 to 3.530	-1.916 to 2.909
Indian	Bias	0.7386	0.2197
	SD of bias	1.147	1.365
	95% Limits of agreement	-1.510 to 2.987	-2.456 to 2.895
British	Bias	1.166	0.4639
	SD of bias	0.9090	1.406
	95% L of Agreement	-0.6159 to 2.947	-2.292 to 3.220

Results: Table 118 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D2C R and D2C L in all populations. All measurements were found between "- 2.79 to 3.53" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.16 mm.

d. Infraorbital Foramen to Infraorbital Rim: Right [D2F R] & Left Side [D2F L]

Figure 55: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2F R (Hokien)

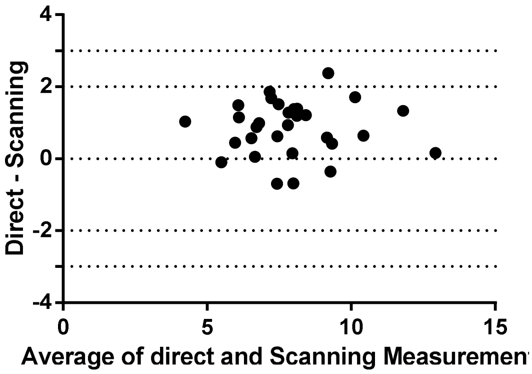


Figure 56: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2F L (Hokien)

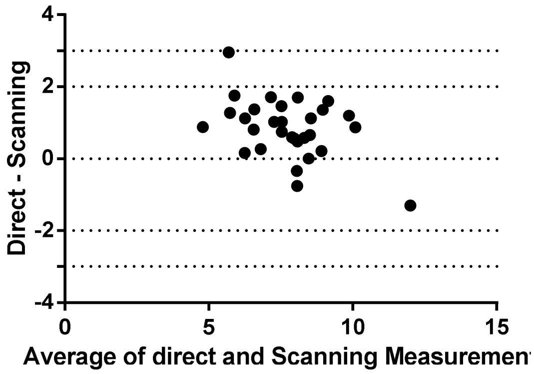


Figure 55 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2F R in the Hokien population. Most measurements were found between "- 0.6 to 2.3" in a positive direction of the mean. [All measurements in mm.]

Figure 56 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2F L in the Hokien population. Most measurements were found between "- 0.78 to 2.45" in a positive direction of the mean. [All measurements in mm.]

Table 119: Descriptive Statistics Related to Distance D2F R & D2F L in the Four Populations

Population	Results	D2F R	D2F L
Hokien	Bias	0.8392	0.8363
	SD of bias	0.7509	0.8241
	95% Limits of agreement	-0.6326 to 2.311	-0.7789 to 2.452
Hylam	Bias	0.8714	0.8971
	SD of bias	0.7694	0.8526
	95% Limits of agreement	-0.6366 to 2.379	-0.7741 to 2.568
Indian	Bias	1.346	1.061
	SD of bias	0.6466	0.7087
	95% Limits of agreement	0.07895 to 2.613	-0.3279 to 2.450
British	Bias	1.465	1.630
	SD of bias	0.7753	1.087
	95% Limits of agreement	-0.05491 to 2.984	-0.5011 to 3.761

Results: Table 119 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D2F R and D2F L in all populations. All measurements were found between "- 0.78 to 3.76" in a positive direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.63 mm.

e. Infraorbital to Supraorbital Foramen (Vertically): Right [D2G R] & Left Side [D2G L]

Figure 57: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2G R (Hylam)

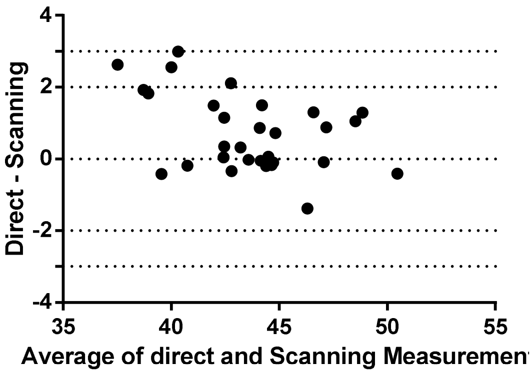


Figure 58: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D2G L (Hylam)

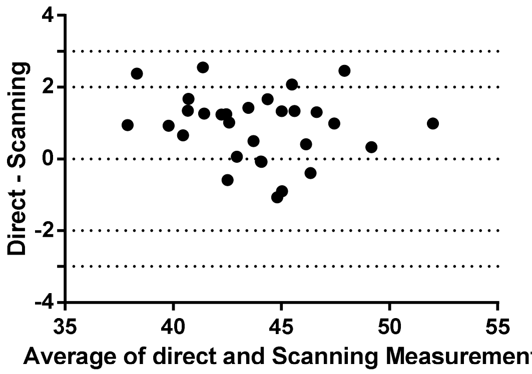


Figure 57 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2G R in the Hylam population. Most measurements were found between "- 1.38 to 2.8" in either direction of the mean. [All measurements in mm.]

Figure 58 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D2G L in the Hylam population. Most measurements were found between "- 0.95 to 2.75" in either direction of the mean. [All measurements in mm.]

Table 120: Descriptive Statistics Related to Distances D2G R & D2G L in the Four Populations

Population	Results	D2G R	D2G L
Hokien	Bias	0.2092	0.2475
	SD of bias	0.6544	0.7255
	95% Limits of agreement	-1.073 to 1.492	-1.174 to 1.669
Hylam	Bias	0.7220	0.8993
	SD of bias	1.070	0.9425
	95% Limits of agreement	-1.375 to 2.819	-0.9480 to 2.747
Indian	Bias	0.9416	0.7108
	SD of bias	0.8350	1.028
	95% Limits of agreement	-0.6950 to 2.578	-1.304 to 2.726
British	Bias	0.7563	0.9593
	SD of bias	1.053	1.045
	95% Limits of agreement	-1.307 to 2.820	-1.090 to 3.008

Results: Table 120 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D2G R and D2G L in all populations. All measurements were found between "- 1.38 to 3.01" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 0.96 mm.

8.3.3 Ipsilateral Distances Related to Mental Foramen in Each Population

(a) Mental Foramen to Symphysis Menti: Right [D3A R] & Left Side [D3A L]

(b) Mental Foramen to Posterior Border of the Ramus: Right [D3B R] & Left Side [D3B L]

a. Mental Foramen to Symphysis Menti: Right [D3A R] & Left Side [D3A L]

Figure 59: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D3A R (Indian)

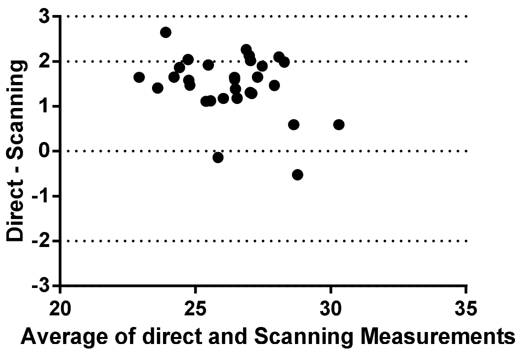


Figure 60: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D3A L (Indian)

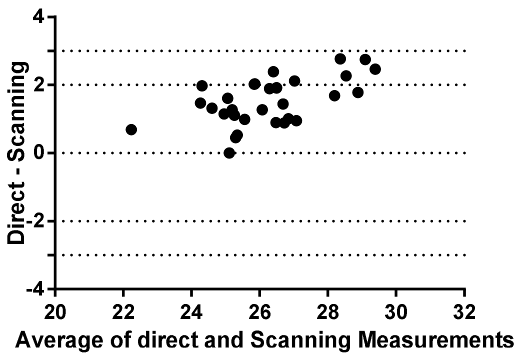


Figure 59 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D3A R in the Indian population. Most measurements were found between "- 0.16 to 2.78" in a positive direction of the mean. [All measurements in mm.]

Figure 60 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D3A L in the Indian population. Most measurements were found between "- 0.14 to 2.87" in a positive direction of the mean. [All measurements in mm.]

Table 121: Descriptive Statistics Related to Distances D3A R & D3A L in the Four Populations

Population	Results	D3A R	D3A L
Hokien	Bias	1.552	1.336
	SD of bias	0.6504	0.5697
	95% Limits of agreement	0.2772 to 2.827	0.2191 to 2.452
Hylam	Bias	1.675	1.360
	SD of bias	0.5929	0.4838
	95% Limits of agreement	0.5130 to 2.837	0.4121 to 2.309
Indian	Bias	1.470	1.505
	SD of bias	0.6704	0.6950
	95% Limits of agreement	0.1560 to 2.784	0.1425 to 2.867
British	Bias	1.379	1.371
	SD of bias	0.7618	1.010
	95% Limits of agreement	-0.1142 to 2.872	-0.6087 to 3.351

Results: Table 121 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D3A R and D3A L in all populations. All measurements were found between "- 0.61 to 3.35" in a positive direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.68 mm.

b. Mental Foramen to Posterior Border of the Ramus: Right [D3B R] & Left Side [D3B L]

Figure 61: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D3B R (British)

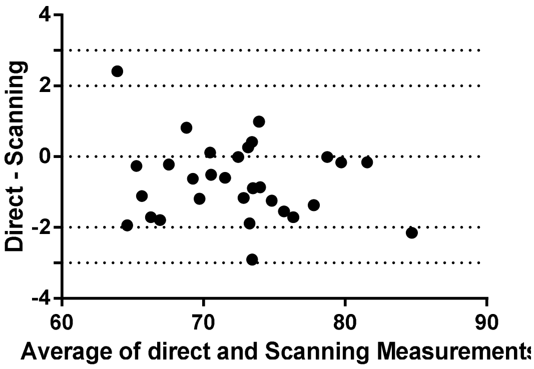


Figure 62: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D3B L (British)

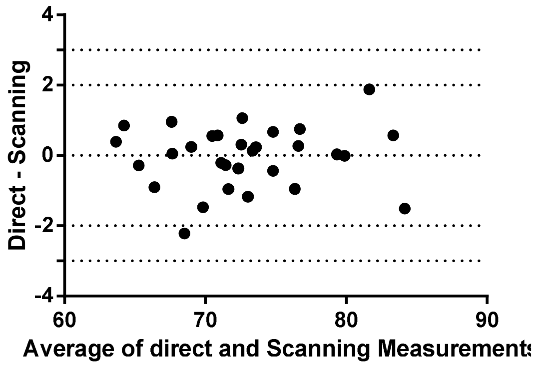


Figure 61 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D3B R in the British population. Most measurements were found between "-2.85 to 1.45" in either direction of the mean. [All measurements in mm.]

Figure 62 shows Bland-Altman plots with very good agreements between electronic calliper (Direct) and scanning measurements with regard to D3B L in the British population. Most measurements were found between "- 1.77 to 1.69" in either direction of the mean. [All measurements in mm.]

Table 122: Descriptive Statistics Related to Distances D3B R & D3B L in the Four Populations

Population	Results	D3B R	D3B L
Hokien	Bias	-0.4530	-0.4800
	SD of bias	0.7056	0.6672
	95% Limits of agreement	-1.836 to 0.9299	-1.788 to 0.8278
Hylam	Bias	-0.5683	-0.5420
	SD of bias	0.8096	0.6244
	95% Limits of agreement	-2.155 to 1.018	-1.766 to .6818
Indian	Bias	-0.7643	-0.4320
	SD of bias	0.9250	0.9473
	95% Limits of agreement	-2.577 to 1.049	-2.289 to 1.425
British	Bias	-0.6990	-0.04100
	SD of bias	1.097	0.8826
	95% Limits of agreement	-2.850 to 1.452	-1.771 to 1.689

Results: Table 122 shows that there were overall very good agreements between electronic calliper and scanning measurements with regard to D3B R and D3B L in all populations. All measurements were found between “- 2.85 to 1.69” in either direction. The bias indicates that the electronic calliper measurements were smaller than the scanning measurements with a maximum of - 0.76 mm.

8.3.4 Ipsilateral Distances Related to Mandibular Foramen in Each Population

(a) Mandibular Foramen to Inferior Border of the Mandible: Right [D4A R] & Left Side [D4A L]

(b) Mandibular Foramen to condylar Notch: Right [D4B R] & Left Side [D4B L]

(c) Mandibular Foramen to Posterior Border of the Ramus at the Same Level: Right [D4C R] & Left Side [D4C L]

(d) Mandibular Foramen to Posterior Border of the Ramus at Occlusal Line: Right [D4D R] & Left Side [D4D L]

(e) Mandibular Foramen to Internal Oblique Ridge at Occlusal Line: Right [D4E R] & Left Side [D4E L]

(f) Internal Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Right [D4G R] & Left Side [D4G L]

(g) External Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Right [D4H R] & Left Side [D4H L]

a. Mandibular Foramen to Inferior Border of the Mandible: Right [D4A R] & Left Side [D4A L]

Figure 63: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4A R (Hokien)

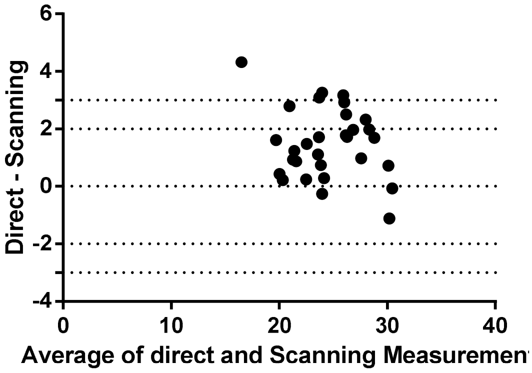


Figure 64: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4A L (Hokien)

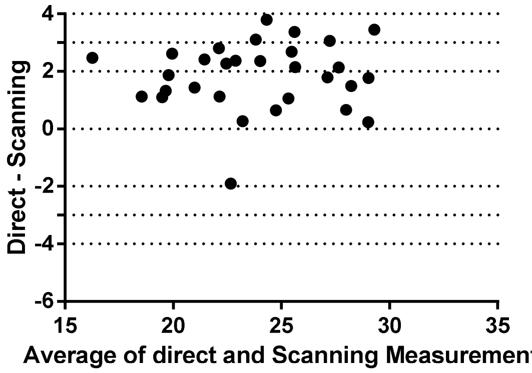


Figure 63 shows Bland-Altman plots with low agreements between electronic calliper (Direct) and scanning measurements with regard to D4A R in the Hokien population. Most measurements were found between "- 0.9 to 3.87" in a positive direction of the mean. [All measurements in mm.]

Figure 64 shows Bland-Altman plots with low agreements between electronic calliper (Direct) and scanning measurements with regard to D4A L in the Hokien population. Most measurements were found between "- 0.47 to 4.15" in a positive direction of the mean. [All measurements in mm.]

Table 123: Descriptive Statistics Related to Distances D4A R & D4A L in the Four Populations

Population	Results	D4A R	D4A L
Hokien	Bias	1.488	1.835
	SD of bias	1.218	1.178
	95% Limits of agreement	-0.8985 to 3.874	-0.4742 to 4.145
Hylam	Bias	1.868	2.697
	SD of bias	2.016	1.353
	95% Limits of agreement	-2.084 to 5.820	0.04535 to 5.349
Indian	Bias	1.361	1.944
	SD of bias	1.552	1.615
	95% Limits of agreement	-1.682 to 4.403	-1.223 to 5.110
British	Bias	0.6495	1.687
	SD of bias	2.000	1.650
	95% Limits of agreement	-3.271 to 4.570	-1.547 to 4.921

Results: Table 123 shows that there were overall low agreements between electronic calliper and scanning measurements with regard to D4A R and D4A L in all populations. All measurements were found between "- 3.27 to 5.82" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 2.7 mm.

b. Mandibular Foramen to Condylar Notch: Right [D4B R] & Left Side [D4B L]

Figure 65: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4B R (Hylam)

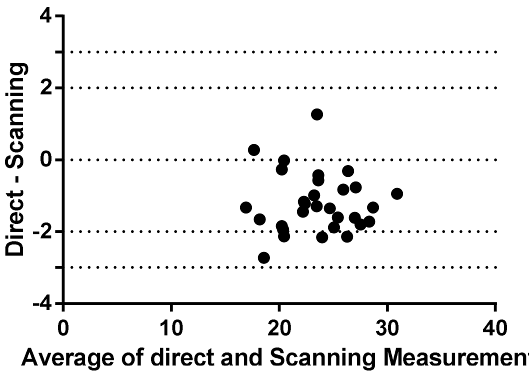


Figure 66: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4B L (Hylam)

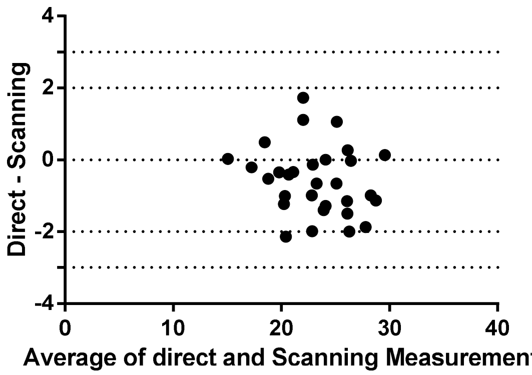


Figure 65 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D4B R in the Hylam population. Most measurements were found between "- 2.84 to 0.45" in a negative direction of the mean. [All measurements in mm.]

Figure 66 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D4B L in the Hylam population. Most measurements were found between "- 2.44 to 1.3" in either direction of the mean. [All measurements in mm.]

Table 124: Descriptive Statistics Related to Distances D4B R & D4B L in the Four Populations

Population	Results	D4B R	D4B L
Hokien	Bias	-0.4820	-0.2330
	SD of bias	0.9543	1.095
	95% Limits of agreement	-2.352 to 1.388	-2.379 to 1.913
Hylam	Bias	-1.196	-0.5733
	SD of bias	0.8390	0,9544
	95% Limits of agreement	-2.841 to 0.4481	-2.444 to1.297
Indian	Bias	-0.9613	-0.7347
	SD of bias	0.8902	1.088
	95% Limits of agreement	-2.706 to 0.7834	-2.868 to 1.399
British	Bias	-0.4198	0.7213
	SD of bias	1.171	1.184
	95% Limits of agreement	-2.715 to 1.875	-3.042 to 1.600

Results: Table 124 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D4B R and D4B L in all populations. All measurements were found between "- 3.04 to 1.91" in either direction. The bias indicates that the electronic calliper measurements were smaller than the scanning measurements with a maximum of - 1.19 mm.

c. Mandibular Foramen to Posterior Border of the Ramus at the Same Level: Right [D4C R] & Left Side [D4C L]

Figure 67: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4C R (Indian)

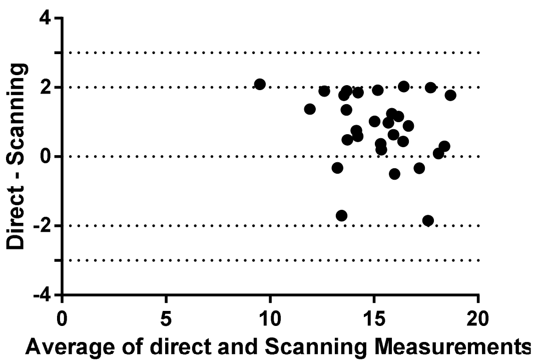


Figure 68: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4C L (Indian)

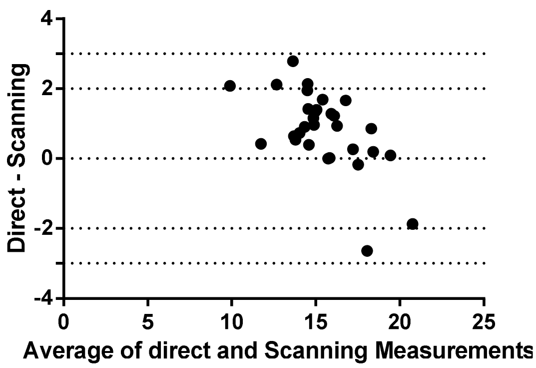


Figure 67 shows Bland-Altman plots with moderate agreements between electronic calliper (Direct) and scanning measurements with regard to D4C R in the Indian population. Most measurements were found between "- 1.22 to 2.86" in either direction of the mean. [All measurements in mm.]

Figure 68 shows Bland-Altman plots with moderate agreements between electronic calliper (Direct) and scanning measurements with regard to D4C L in the Indian population. Most measurements were found between "- 1.37 to 3.01" in either direction of the mean. [All measurements in mm.]

Table 125: Descriptive Statistics Related to Distances D4C R & D4C L in the Four Populations

Population	Results	D4C R	D4C L
Hokien	Bias	0.9443	0.9687
	SD of bias	0.8029	0.8785
	95% Limits of agreement	-0.6294 to 2.518	-0.7532 to 2.691
Hylam	Bias	0.9577	0.9840
	SD of bias	0.8298	0.8099
	95% Limits of agreement	-0.6688 to 2.584	-0.6034 to 2.571
Indian	Bias	0.8164	0.8185
	SD of bias	1.041	1.118
	95% Limits of agreement	-1.223 to 2.856	-1.374 to 3.010
British	Bias	1.191	1.102
	SD of bias	0.7753	0.7929
	95% Limits of agreement	-0.3287 to 2.711	-0.4517 to 2.656

Results: Table 125 shows that there were overall moderate agreements between electronic calliper and scanning measurements with regard to D4C R and D4C L in all populations. All measurements were found between "- 1.37 to 3.01" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.19 mm.

d. Mandibular Foramen to Posterior Border of the Ramus at Occlusal Line: Right [D4D R] & Left Side [D4D L]

Figure 69: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4D R (British)

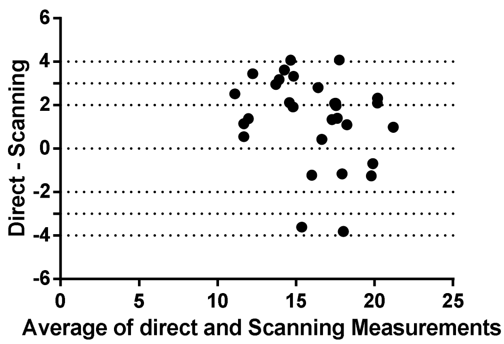


Figure 70: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4D L (British)

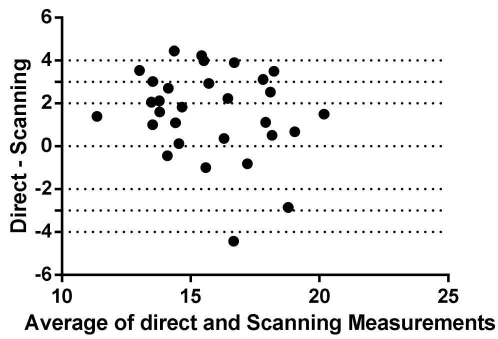


Figure 69 shows Bland-Altman plots with very low agreements between electronic calliper (Direct) and scanning measurements with regard to D4D R in the British population. Most measurements were found between "- 2.59 to 5.33" in either direction of the mean. [All measurements in mm.]

Figure 70 shows Bland-Altman plots with very low agreements between electronic calliper (Direct) and scanning measurements with regard to D4D L in the British population. Most measurements were found between "- 2.49 to 5.55" in either direction of the mean. [All measurements in mm.]

Table 126: Descriptive Statistics Related to Distances D4D R & D4D L in the Four Populations

Population	Results	D4D R	D4D L
Hokien	Bias	2.041	2.129
	SD of bias	1.626	1.570
	95% Limits of agreement	-1.145 to 5.227	-0.9485 to 5.207
Hylam	Bias	1.191	1.423
	SD of bias	1.574	1.600
	95% Limits of agreement	-1.895 to 4.276	-1.712 to 4.559
Indian	Bias	2.572	1.992
	SD of bias	1.585	1.700
	95% Limits of agreement	-0.5358 to 5.679	-1.340 to 5.324
British	Bias	1.369	1.532
	SD of bias	2.021	2.050
	95% Limits of agreement	-2.592 to 5.331	-2.487 to 5.550

Results: Table 126 shows that there were overall very low agreements between electronic calliper and scanning measurements with regard to D4D R and D4D L in all populations. All measurements were found between "- 2.59 to 5.68" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 2.57 mm.

e. Mandibular Foramen to Internal Oblique Ridge at Occlusal Line: Right [D4E R] & Left Side [D4E L]

Figure 71: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4E R (Hokien)

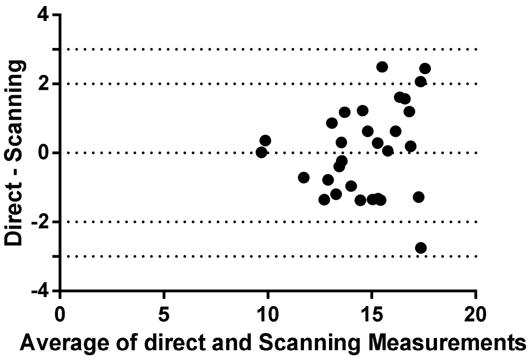


Figure 72: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4E L (Hokien)

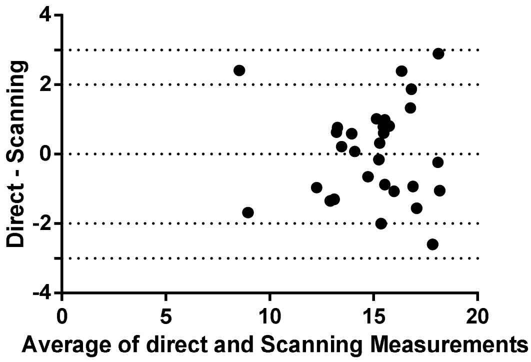


Figure 71 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D4E R in the Hokien population. Most measurements were found between "- 2.49 to 2.64" in either direction of the mean. [All measurements in mm.]

Figure 72 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D4E L in the Hokien population. Most measurements were found between "- 2.66 to 2.74" in either direction of the mean. [All measurements in mm.]

Table 127: Descriptive Statistics Related to Distances D4E R & D4E L in the Four Populations

Population	Results	D4E R	D4E L
Hokien	Bias	0.0720	0.04267
	SD of bias	1.309	1.378
	95% Limits of agreement	-2.493 to 2.637	-2.657 to 2.743
Hylam	Bias	-0.3593	-0.4130
	SD of bias	1.014	1.304
	95% Limits of agreement	-2.347 to 1.628	-2.969 to 2.143
Indian	Bias	-0.06258	-0.5483
	SD of bias	1.377	1.088
	95% Limits of agreement	-2.762 to 2.637	-2.681 to 1.585
British	Bias	0.2522	0.1702
	SD of bias	1.110	1.163
	95% Limits of agreement	-1.924 to 2.428	-2.109 to 2.449

Results: Table 127 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D4E R and D4E L in all populations. All measurements were found between "- 2.97 to 2.74" in either direction. The overall bias indicates that the electronic calliper measurements were similar to the scanning measurements with a maximum of 0.25 mm.

f. Internal Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Right [D4G R] & Left Side [D4G L]

Figure 73: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4G R (Hylam)

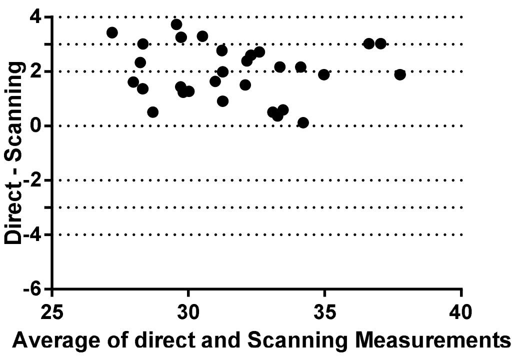


Figure 74: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4G L (Hylam)

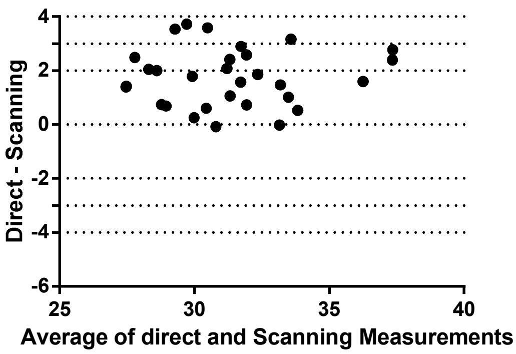


Figure 73 shows Bland-Altman plots with moderate agreements between electronic calliper (Direct) and scanning measurements with regard to D4G R in the Hylam population. Most measurements were found between "0.02 to 3.93" in a positive direction of the mean. [All measurements in mm.]

Figure 74 shows Bland-Altman plots with good agreements between electronic calliper (Direct) and scanning measurements with regard to D4G L in the Hylam population. Most measurements were found between "- 0.36 to 3.84" in a positive direction of the mean. [All measurements in mm.]

Table 128: Descriptive Statistics Related to Distances D4G R & D4G L in the Four Populations

Population	Results	D4G R	D4G L
Hokien	Bias	1.874	1.844
	SD of bias	0.8750	1.037
	95% Limits of agreement	0.1586 to 3.589	-0.1888 to 3.876
Hylam	Bias	1.957	1.743
	SD of bias	1.007	1.072
	95% Limits of agreement	-0.01710 to 3.931	-0.3571 to 3.844
Indian	Bias	2.139	2.253
	SD of bias	1.040	1.059
	95% Limits of agreement	0.1005 to 4.178	0.1780 to 4.329
British	Bias	2.032	2.014
	SD of bias	1.189	1.264
	95% Limits of agreement	-0.2991 to 4.363	-0.4638 to 4.492

Results: Table 128 shows that there were overall moderate agreements between electronic calliper and scanning measurements with regard to D4G R and D4G L in all populations. All measurements were found between "- 0.46 to 4.49" in a positive direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 2.25 mm.

g. External Oblique Ridge to Posterior Border of the Ramus at Occlusal Line: Right [D4H R] & Left Side [D4H L]

Figure 75: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4H R (Indian)

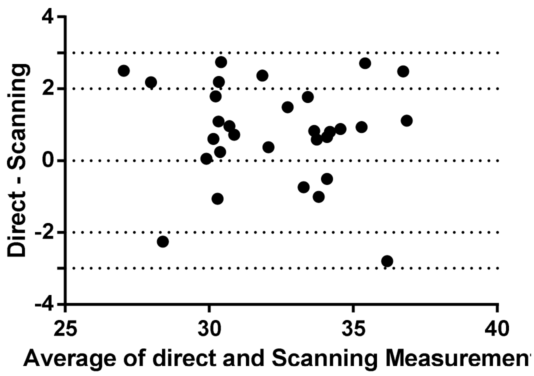


Figure 76: Bland-Altman Plot of Electronic Calliper and Scanning Measurements of D4H L (Indian)

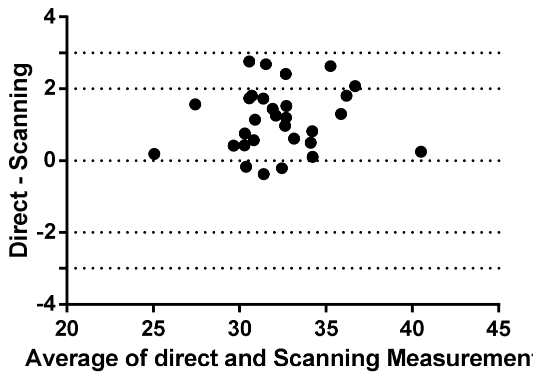


Figure 75 shows Bland-Altman plots with moderate agreements between electronic calliper (Direct) and scanning measurements with regard to D4H R in the Indian population. Most measurements were found between "-1.94 to 3.52" in either direction of the mean. [All measurements in mm.]

Figure 76 shows Bland-Altman plots with moderate agreements between electronic calliper (Direct) and scanning measurements with regard to D4H L in the Indian population. Most measurements were found between "-0.6 to 2.86" in either direction of the mean. [All measurements in mm.]

Table 129: Descriptive Statistics Related to Distances D4H R & D4H L in the Four Populations

Population	Results	D4H R	D4H L
Hokien	Bias	1.273	1.039
	SD of bias	1.023	0.9953
	95% Limits of Agreement	-0.7320 to 3.277	-0.9117 to 2.990
Hylam	Bias	1.046	0.7970
	SD of bias	1.301	0.9686
	95% Limits of agreement	-1.505 to 3.596	-1.102 to 2.696
Indian	Bias	0.7898	1.130
	SD of bias	1.394	0.8846
	95% Limits of agreement	-1.942 to 3.521	-0.6035 to 2.864
British	Bias	0.7089	0.9359
	SD of bias	0.9515	1.009
	95% Limits of agreement	-1.156 to 2.574	-1.043 to 2.914

Results: Table 129 shows that there were overall good agreements between electronic calliper and scanning measurements with regard to D4H R and D4H L in all populations. All measurements were found between "- 1.94 to 3.6" in either direction. The bias indicates that the electronic calliper measurements were larger than the scanning measurements with a maximum of 1.27 mm.

Chapter 9
Discussion

This principal aim of this study was to obtain comparative measurements relating to four cranial foramina in three different ethnic populations. The measurements were predicated on defined ‘points’ and other anatomical landmarks. It follows that both the accuracy and precision of these measurements depends on the definition of these ‘points’ and landmarks which determine the measured distances.

The discussion will therefore centre on the following:

- Definition of points and landmarks
- The skulls used
- Statistics
- Results

Definition of points and landmarks: Accuracy is the proximity of measurement results to the true value; precision, the repeatability, or reproducibility of the measurement. In the fields of science, the accuracy of a measurement system is the degree of closeness of measurements of a quantity to that quantity's actual or true value. The precision of a measurement system is the degree to which repeated measurements under unchanged conditions show the same results. A measurement system can be accurate but not precise, precise but not accurate, neither, or both. For example, if an experiment contains a systematic error, then increasing the sample size generally increases precision but does not improve accuracy. The result would be a consistent yet inaccurate string of results from the flawed experiment. Eliminating the systematic error improves accuracy but does not change precision.

The initial step in eliminating systematic error was to define the points and anatomical landmarks used in the study (Table 14– 17; pp. 104 & 105). Then a series of preliminary studies were undertaken to increase reproducibility (P 66).

However, these efforts do not eliminate the problem of inter-studies comparisons. There are several issues which make it difficult to compare the results of this study with data from previous studies. The most obvious is the definition of “points” from which measurements were made.

Several studies (see literature review) used the centre of foramina as the point from which measurements were taken. Such a “point” is both difficult to define and locate and even more difficult on which to position the tip of a calliper. There is a greater chance of introducing a measurement error when using such a “point”. In the present study, the most medial point on the supraorbital, infraorbital and mental foramina and the most inferior anterior point on the mandibular foramen were used because these points are more easily defined, giving more reproducible and more accurate measurements. Some previous studies did use a point on the periphery of the foramen similar to that defined in the present study. Examples are the most medial point on the supraorbital, infraorbital and mental foramina and the most inferior anterior point on the mandibular foramen (Nicholson, 1985; Webster *et al.*, 1986; Santini & Land, 1990). In another study (Kazkayasi *et al.*, 2001) different ‘point’ definitions were used for different foramina and this made it difficult to determine the relative position of the foramina to their related landmarks.

More problematic were studies in which the authors failed to define or report the point from which measurements are made. No definition is given for the point on the supraorbital foramen (Gumusburun *et al.*, 2002; Saylam *et al.*, 2003; Cheng *et al.*, 2006; Erdogmus & Govsa, 2007), on the infraorbital (McKinstry, 1987; Triandafilidi *et al.*, 1990; Canan *et al.*, 1999; Kazkayasi *et al.*, 2003; Rahman *et al.*, 2009) on the mental foramina (Green, 1987; Green & Darvell, 1988; Fabian, 2007; Guo *et al.*, 2009) and 17 other papers detailed in the literature review, or where both the supraorbital and infraorbital foramina were reported in the same study (Hwang & Baik, 1999; Karakas *et al.*, 2003; Kazkayasi *et al.*, 2008).

Further issues complicating study comparisons occur when different definitions of ‘points’ were used in different studies compared to the definitions used in the present study. In the following studies the defined point on the supraorbital (Webster *et al.*, 1986; Aziz *et al.*, 2000; Shimizu *et al.*, 2008), the infraorbital (Matsuda, 1927; Aziz *et al.*, 2000; Elias *et al.*, 2004) and the mental foramina (Matsuda, 1927; Tebo & Telford, 1950; Friedman *et al.*, 1985; Santini & Land, 1990; Yesilyurt *et al.*, 2008) differed from the definition used currently.

A universal acceptance of precise definitions of all landmarks and precise definitions of all "points" on these anatomical landmarks is a necessary prerequisite for future study comparisons.

The skulls used: For meaningful data, knowledge of both the source and age of skull is necessary. The precise geographic origin of both Chinese and Indian cohorts was known, having been accurately documented prior to their deposition in The Anatomy Section, The University of Edinburgh. Not only is it known where they originated from but the records are very suggestive of the fact that each of the three cohorts is very homogenous. Additionally an accurate age of all the Chinese skulls was known from burial records, making these two cohorts somewhat unique. This knowledge was used to verify the Miles method of aging (p 85) and thereafter the age of all other skulls used in the study.

Such homogeneity is not at all common in other studies. Many studies fail to state the source or indeed the ethnicity of the populations used. (Nicholson, 1985; McKinstry, 1987; Canan *et al.*, 1999; Berge & Bergman, 2001; Mowlavi *et al.*, 2002; Saylam *et al.*, 2003; Agthong *et al.*, 2005; Captier *et al.*, 2006; Nurten *et al.*, 2008; Ashwini *et al.*, 2012) and in fifty two other studies (see literature review).

The British cohort used in this thesis was not from one location. They were documented as being either Anglo-Saxon (English) or Dark Ages (Scottish). Caution must be exercised when drawing conclusions from such disparate collections. Smith (1984) and Lavelle (1970) reported that a good relationship existed between tooth attrition patterns and the type of food. Hunter-gatherers, whose food was rough, showed worn, almost flat, molar surfaces. In populations, whose food was based on wheat or corn, wear patterns changed and the worn molar surfaces tended to be more oblique. The latter developed higher angles than did hunter-gatherers, ultimately reaching a 10° difference. This suggests that caution must be exercised when using tooth wear patterns as an age assessment criterion. Miles (1962) and Brothwell

(1981) however were of the opinion that British populations' tooth wear did not appear to have changed much from Neolithic to Medieval times, and his attrition chart should be roughly correct for all these periods. Not until the introduction of sugar, would there have been a great difference in the food which would affect tooth wear patterns. The fact that there was a close correlation between the Chinese tooth wear patterns and the "patterns" as described by Miles and Brothwell in their charts, testifies to this statement to a certain extent.

As has been mentioned, both Chinese cohorts had age recorded at death. This allowed two important issues to be resolved.

First, a preliminary study confirmed the validity of the Miles method of ageing skulls using tooth attrition patterns. Miles called for such a confirmation, using his methods (Miles, 1962) when new populations were studied. This however requires a large number of skulls with an age range from about 6 years onwards. Knowing the age of the Chinese skulls, and comparing the tooth attrition patterns, presented new and unique validation of his method.

Secondly, once the Miles attrition pattern method was validated, the Indian and British skulls were age assessed. This additional (derived) data allowed the following:

1. To ascertain if the four populations have a similar age distribution.

2. To see if there was any difference in measured distances in relation to the maxillofacial foramina with respect to the age in adult populations.

For estimation the age of the skulls, an age estimation calculator was devised based on Miles and Brothwell Charts (pp 86 & 93) which allows a rapid age estimation of skulls and makes data collection quicker and easier.

Following on from this, statistical analysis of the data could be used in a way not undertaken in many previous studies.

Sexual dimorphism has been reported in many studies where skulls of known sex were used (Wang *et al.*, 1986; Sankar *et al.*, 2011) and forty three other papers: (see literature review). All the Chinese skulls from both cohorts were recorded at death as male, so sexual dimorphism could not be investigated. This places the current study in a group of similar studies where either subjects were of one sex (Oguz & Bozkir, 2002; Fabian, 2007), or subjects of unknown sex (Tebo & Telford, 1950; Ashwini *et al.*, 2012). In studies where sexual dimorphism was studied, there was not a clinically statistically significant difference between the two sexes (McKinstry, 1987; Hwang & Baik, 1999; Aziz *et al.*, 2000; Olasoji *et al.*, 2004).

All skulls were, as stated previously, obtained from the large collection in the Anatomy Section, The University of Edinburgh. The number of available skulls was therefore limited. A power calculation was undertaken, however in many respects this need not have been done as the results are presented with 95% confidence intervals and 95% limits of agreement which allows the reader to obtain an insight into the accuracy of the measurement procedure.

When taking electronic calliper measurements, crania were placed on the apparatus so that contacts were made by the maxillary teeth and the mastoid processes, the occipital condyle or the external occipital protuberance on the base platform. This resulted in the "imaginary horizontal lines" being parallel to the horizontal platform but not parallel to the horizontal position of the skull. A possible way to overcoming this would be to cut the occipital condyles to make sure that all of the skulls were positioned on the mastoid processes. This could not be contemplated as this would lead to damage and destruction to the skulls, and was completely contraindicated. At all times, the integrity of the collection was maintained. To overcome this problem an alternative method of measurement was sought. (Vide infra)

In the measurement procedures, with both maxilla and mandibles, there were some limitations when the electronic calliper measurement method using the electronic calliper was used, including the following

1. The Frankfurt plane was difficult or impossible to achieve physically, though it had been used by some authors before (Morant, 1923; Macedo *et al.*, 2009). It was a complicated process and the accuracy was questionable because there was no specific apparatus available to achieve the plane accurately. It was difficult to fix the cranium in a stable position at all times while taking

measurements. Theoretically, it is easy to define, but it is very difficult to achieve practically.

2. The plane of the cranium had some limitations: Crania were placed on the apparatus in the standard basal position so that contacts were made by the maxillary teeth and mastoid processes or occipital condyles on the base platform.
3. Plane of Morant: This is easy to define theoretically (Morant, 1923) but it is difficult to achieve for all mandibles, especially for those mandibles that had a convex lower border. In these cases it was difficult to stabilise the mandible. In a few mandibles which displayed this "rocking displacement", pins or plasticine were used to stabilise the mandible to prevent movement while taking measurements.
4. Anatomical Midline: It was difficult to obtain this precisely, especially in the cranium. It difficult to define the midline using only two points in one plane. Some authors used a silk to delineate the midline (Webster *et al.*, 1986). This method was tired but proved equally difficult because it was difficult to maintain the silk in a stable position while taking measurements.
5. Inferior border of mandible: It was difficult some times to measure the distance between the mental or mandibular foramina to the inferior border of the mandible, especially if the inferior border point was not in contact with the horizontal platform. Also in the case of the mandibular foramen, the most inferior point of the mandible was not at the same vertical plane as the mandibular foramen.

In order to standardise measurements by standardising the position of either mandibles or crania on the measuring platform two types of spirit levels were used. A large spirit level was used to check the level of the horizontal platform and the pencil holder arm and to make sure that they were always in the horizontal plane. A small spirit level with a magnetic surface was attached to the electronic digital calliper, enabling the calliper ruler to be maintained in a horizontal plane or vertical plane when taking measurements.

An electronic digital calliper is easy to use, quick and simple to operate, cheap and universally available. However it has an accuracy limited by the vernier scale. Readings are dependent on the operator ability both in terms of eyesight and the force and feel in judging when to stop closing the jaws. Calliper measurements do not follow the curvature of the skull but measure the shortest distance between the points.

Because of the above limitations of calliper measurements, the study was duplicated using 3D laser scanning in an effort to evaluate if this could prove to be more accurate alternative. As the 3D laser scanner was portable, it was immediately obvious that, if needed, such a method and apparatus could be taken to locations such as museums or other sites.

The results of the present study showed that the measurements by both electronic digital calliper and laser scanning were comparable. Thus for the following reasons, laser scanning should be considered the method of choice in future studies.

Advantages of 3D laser scanner: It is relatively easy to learn how to use both the hardware and the software. It is portable and relatively inexpensive. The skull (or other items) can be positioned in a virtual horizontal position without the requirement of vertical pressure or fixation bars as in the calliper method. "Rocking" of mandibles which have a convex lower border is overcome and is no longer a problem. Subject matter (skulls) can be easily moved in any direction for ease of measurement, an example being the ability to position crania and identify the Frankfurt plane with a high degree of reproducibility. Similarly, mandibles are easily "positioned" in the Morant position. It can be used anytime anywhere to scan the skulls. The scanned skulls' data were saved and accessed remotely, either across the internet or by CD. It is easy to move the subject in any direction without any possibility of changing its orientation or direction. There are options to "zoom" in on the subject (as previously described in Method and Material Section) to make sure the planes that were used such as the Frankfurt and horizontal basal plane, were exactly in the correct position. The "occlusal line" was drawn easily without obstruction from any over eruption of molar tooth. Because it is an imaginary line it can be drawn, using the laser scanning, relative to on the occlusal surface of one molar tooth.

The following is a short list of the advantages found in practice where collecting data for this study.

The distances from the mental or mandibular foramina to the inferior border of the mandible were obtained accurately even if it was not in contact with the plane because the software only allows data to be collected from the “bony surfaces”. The edge of the bone can be easily recognised. Any unwanted planes can be hidden if they cause obstructions to the measurements and can be displayed again without any change or effect on the position of the subject.

In addition it allows repetition of any measurement because the subject’s data have been saved in the measurement position. The points on the foramina or the anatomical landmarks could be marked on/off easily. Another very useful option is the “Orient Through Three Points” option which enables the plane to be defined by three anatomical landmarks (e.g. nasion, anterior nasal spine and external occipital protuberance/ external occipital crest). Once three landmarks are defined a plane is generated which passes through them. This allowed a more accurately defined midline plane to be generated.

There are other options such as “fill holes” and “Add fine detail” which enables defects to be appears as bone, thus allowing the measuring of distances between the infraorbital foramen and midline where it was very difficult or impossible when taking electronic calliper reading from skulls due to the presence of the nasal aperture. There are some limitations such as the “ruler” tool which like electronic digital calliper, measures the shortest distances between points and does not follow the curvature of the subject.

Statistics: A very good piece of advice for all researchers is to consult a statistician prior to collecting data. Statistical analysis is the ultimate objective assessment of data. Statistical advice was sought and the following tests were used as advised. For statistical analysis, the paired t test was used to analyse intra-population comparisons from the right and left sides in the same population, whereas, the unpaired t test was used to analyse inter-population comparisons between the ipsilateral distances in the four population groups. The former being paired measurements, the later unpaired.

The Bland-Altman statistical approach was used rather than conventional correlation statistics as the latter is considered to be inadequate and misleading (Bland & Altman, 1986). It is important that any recommended newer approach does not cause problems in interpretation of data. The Bland-Altman plot approach can be used to compare the two methods or between two observations. In both situations it gives an insight into how much the new method is likely to differ from the old method, or one observation from another. If the new method does not cause problems in clinical interpretation, it can replace the old method or both could be used interchangeably. When comparing clinical measurements obtained using a new measurement technique with those obtained by the use of an established one, is often needed to see whether they agree sufficiently to justify the replacement of the old by the new method. Such comparative investigations are often analysed inappropriately, notably by using correlation coefficients. It is beyond the scope of this thesis to argue this point further, and being the statistical approach recommended by the university statistician, it was used to compare the electronic digital calliper method with the 3D laser scanning approach.

Additional statistical approaches, not previously identified in the literature were used: The 95% Limit of agreement gives a statement or indication of the reproducibility of a method or stated in another way, the degree of consistency.

The “bias” is the average difference between the electronic digital calliper method using the electronic calliper and the scanning method using 3D Laser Scanning for any distance. If the bias is positive it indicates the electronic digital calliper method gives larger measurements than scanning method, but if the bias is negative this is indicative of the electronic digital calliper method gives smaller measurements than the scanning method.

“Weighted Kappa”, was used to analyse the validation of the Brothwell method using skulls of known age and intra-observer and inter-observer scoring of occlusal tooth wear patterns. It is used when data are categorised or ordered measurements rather than continuous.

Discussion of the Electronic Digital Calliper Method:

1. Intra-Population Comparisons between the Right and Left Sides in Each Population Group:

Distances Related to the Supraorbital Foramen: In the present study, the mean distances related to the right and left supraorbital foramina were similar with no significant differences in each population of the four populations. These statistical significances were considered as not clinically relevant as any measurement less than about 3mm has no meaning clinically. Overall, there were no significant differences with regard to all distances related to the supraorbital foramen region on the right and left sides where comparisons are made between the right and left sides in each population of the four populations.

The distances from the midline to the defined point on the supraorbital foramen (Table 20, p 140) for all four populations used in the present study were similar to these reported by Chung *et al*. (1995), Gupta (2008), Nurten *et al*. (2008), Trivedi *et al.* (2010) and Ashwini *et al.* (2012). However, they differ from other studies including Webster *et al.* (1986), Aziz *et al.* (2000), Cutright *et al.* (2003), Saylam *et al.* (2003), Agthong *et al.* (2005), Apinhasmit *et al.* (2006), Cheng *et al.* (2006) and Tsui (2009). The difference may because these studies measured the distance from the centre of the foramen, different defined points or the point was undefined. Additionally there could have been a mixture of sexes in the sample or the measurements were taken on the radiographic or ultrasound imaging. An example of this relates to measurements taken using the temporal crest as a bony landmark. This can be reliably palpated and used for measurement purposes and for this reason it has been used previously and in the present study.

Agreement occurs for measured distances from the temporal crest to the most medial point of the supraorbital foramen in this study (Table 21, p 141) and those of Cutright *et al.* (2003) and Apinhasmit *et al.* (2006) but not with Gupta (2008) and may be because the latter study measured the distance from the centre of the foramen. The temporal crest line is not straight but curved and so a change in the point used for measurement will result in a change in measured distance.

Distances Related to the Infraorbital Foramen: In each of the four populations, there was no significant differences between any of the measured distances relating to the infraorbital foremen on both the right and left sides. This was in contradiction to the study by Macedo *et al.* (2009) who reported bilateral asymmetry between the right and left sides with regard to the distance from the infraorbital foramen to the infraorbital rim. In the present study, the mean distances between the right and left infraorbital foramina in all populations were found to be ranged between 50.00 to 53.17 mm and corresponded to data given by both Song *et al.* (2007) or Gupta (2008).

A literature search failed to find data from other studies relating to measurements from the defined point on the infraorbital foramina to the midline at the horizontal plane of the supraorbital foramina (see definition in Table 15, p104), on both sides (Table 23 on p 141) for all four population used in the present study, and so comparisons could not be made. The mean distances from the defined point on the infraorbital foramina to the anterior nasal spine on both sides (Table 24, p 142) for all four population used in the present study ranged between 28.20 mm to 30.49 mm, and differed from results reported by Agthong *et al.* (2005). The most likely explanation is due to differences in defined points. In Agthong's study measurements were taken from the centre of the foramen to the anterior nasal spine, whereas, in the present study, the most medial point was used and the distance was measured between the levels of the foramen to the anterior nasal spine at the same horizontal plane.

The mean distances between the infraorbital foramina to the zygomatico-maxillary suture on both sides ranged between 7.23 mm to 9.29 mm (Table 26, p 142) for all four populations used in the present study and corresponded to those reported by Smith *et al.* (2010), but differed from data by Gupta (2008) again due to differences in defined points, the later measured the distance from the centre of the foramen. Where, distances were measured from the same or similarly defined points, such as the mean vertical distances between the most medial point of the supraorbital foramen and the most medial point of the infraorbital foramen on the same side, data from Hokien, Hylam and British populations (Table 27, p 142) they were similar to the findings of Gupta (2008) as well as Chung *et al.* (1995), Aziz *et al.* (2000), Apinhasmit *et al.* (2006) and Ilayperuma *et al.* (2010). These facts suggest that a call be made for agreed definitions to be used in the future to allow meaningfull comparisons between studies.

The mean distance of the infraorbital foramen from the infraorbital rim at the same vertical plane (Table 26, p 142) for all four populations used in the present study, was found to range between 6.84 mm and 8.49 mm, and these distances were similar to those given by Triandafilidi *et al.* (1990), Chung *et al.* (1995), Rahman *et al.* (2009), Boopathi *et al.* (2010) and nine others (see literature review), but larger than those in other studies (Canan *et al.*, 1999; Apinhasmit *et al.*, 2006; Tsui, 2009; Ilayperuma *et al.*, 2010) The inferior orbital rim may be valuable in identifying the danger zone of location of the infraorbital neurovascular bundle during dissection of the communicated fractures of the anterior maxillary wall and inferior orbital rim and other surgical procedures (Cutright *et al.*, 2003). From the above results, there was bilateral symmetry on both sides in all distances related to the infraorbital foramen region in each of the four populations. Overall, there were no significant differences with regard to all distances related to the infraorbital foramen on the right and left sides. This contradicts the work of Elias *et al.* (2004).

Distances Related to the Mental Foramen: The mean distances between the mental foramina to the symphysis menti on both sides in all populations were ranged between 26.54 mm to 28.20 mm (Table 29, p 143). These results approximate to the results of Tebo & Telford (1950), Wang *et al.* (1986), Lopes *et al.* (2010), Sankar *et al.* (2011) and nine others (see literature review), but differ from Chung *et al.* (1995) in Korean, Cutright *et al.* (2003) in Black and White American, Smajilagic & Dilberovic (2004), Gupta (2008) in North-West Indian, Agarwal & Gupta (2011) in South Gujarat population, Budhiraja *et al.* (2013) in North Indian population and Parmar *et al.* (2013) in Eastern Indian population.

The mean distances between the mental foramina to the posterior border of the ramus on both sides in all populations ranged between 68.78 mm to 72.74 mm (Table 30, p 143). These results were similar to the results of Santini & Land (1990), Apinhasmit *et al.* (2006), Captier *et al.* (2006) and Sankar *et al.* (2011) but differ from Tebo & Telford (1950), Wang *et al.* (1986), Prabodha & Nanayakkara (2006), Budhiraja *et al.* (2013) and Parmar *et al.* (2013) where differences again are due in the main to the use of differently defined points. A common point of reference in previous studies, including these cited here, was the centre of the foramen or from the posterior margin of the foramen, whereas, in the present study, the most medial point was used. The centre of the foremen, as previously stated is a difficult point to obtain with precision; there will obviously be a difference between measurements using the posterior as opposed to the anterior boarder of any foramen, equal to the size of the foremen.

The supraorbital, infraorbital and mental foramina were stated by Chung *et al*. (1995), Gupta (2008) and Tsui (2009) to be in the same sagittal plane whereas Chung *et al.* (1995) found it most commonly was on the sagittal plane passing through the supraorbital foramen. Whereas, (Cutright *et al.*, 2003) found the supraorbital, infraorbital and mental foramen may not be closely aligned through a vertical line drawn through them. This study shows that the mean distances between the infraorbital foramina to the supraorbital foramina (horizontally) at level of the supraorbital foramina in all populations ranged between – 2.04 mm to – 3.90 mm. These results indicate that the most medial point of the infraorbital foramen lay laterally to the sagittal plane that passes through the most medial point of the supraorbital foramen and parallel to the midline.

The overall findings from the present study conclude that there was bilateral symmetry for all measured distances related to the mental foramen region in each of the four populations and was in agreement with the studies of Phillips *et al.* (1992), Olasoji *et al.* (2004), Amorim *et al.* (2008), Gupta (2008) and Gungor *et al.* (2006). Asymmetry was reported by Kekere-Ekun (1989), Fabian (2007), Lopes *et al. (*2010) and AL-Khateeb *et al.* (2007).

Distances Related to the Mandibular Foramen: In the present study, the mandibular foramen was mostly situated approximately halfway along a plane between the anterior and posterior border of the ramus, in agreement with Nicholson (1985) or halfway along the plane between the mandibular notch and the inferior border of the mandible (Nicholson, 1985). However, of all cranial foramina, there are more differences in stated positions for this foramen. These include: the mandibular foramen was stated to lie just posterior to the middle of anteroposterior line of the ramus horizontal to the plane of Morant at the level of the narrowest anteroposterior dimension of the ramus by Hetson *et al.* (1988), Mbajiorgu (2000), Oguz & Bozkir (2002), Kositbowornchai *et al.* (2007) and Poonacha *et al.* (2010); in the vertical direction to lie just superior to the midpoint of the height of the ramus by Mbajiorgu (2000) and Kositbowornchai *et al.* (2007); the foramen was positioned approximately in the third quadrant anteroposteriorly of the ramus by Hayward *et al.*, (1977); the posterior third of the ramus in both vertical and horizontal directions by da Fontoura *et al.* (2002). There was no significant difference noted in the location of mandibular foramen in Asiatic or black and white Americans (Hayward *et al.*, 1977). Differences in stated positions can often be explained by the use of different population and different point on the inferior border of the mandible, an obvious example being a comparison between the present study and that of Oguz & Bozkir (2002).

Approximately similar measured distances were obtained in the present study to those of (Kaffe *et al.*, 1994; Jerolimov *et al.*, 1998; Oguz & Bozkir, 2002; Huang, 2003; Kilarkaje *et al.*, 2005) when measuremnats were taken between the mandibular foramina to the condylar notch (Table 32, p 144); and those of Hayward *et al.* (1977), Jerolimov *et al.* (1998) and Huang (2003) when measuremnats were taken between the mandibular foramina to the posterior border of the ramus at the level of the mandibular foramina (Table 33, p 145); and those of Hayward *et al.* (1977) and Jerolimov *et al.* (1998) when measuremnats were taken between the mandibular foramina to the internal oblique ridge at the occlusal line. However they differ from the study of Kilarkaje *et al.* (2005), the difference may be because this study measured the distance from the centre of the foramen, whereas in the present study, the most inferior anterior point was used.

These differences could lead to differences in advice with respect to administering inferior mandibular dental block injection. Positioning of syringes is often given relative to the occlusal plane. In the present study, the mean measured distances between the mandibular foramina to the vertically occlusal line at the same vertical plane ranged from -3.45 (± 3.49) mm to -4.73 (± 3.30) mm (Table 36, p 146) that is to say, most mandibular foramina were situated below the level of the posterior extension of the occlusal line. This is in agreement with Nicholson (1985), Hetson *et al.* (1988) but not with Mbajiorgu (2000) who stated the most common position of the foramen was at the same level with the occlusal plane in 47.1%, above the plane in 29.4%, and below the plane in 23.5% of the cases, and Movahhed *et al.* (2011) who reported that the mandibular foramen was above the occlusal plane in 86% in both sexes. Hwang *et al.* (1990) reported the mandibular foramen moved upward with age, from below the occlusal plane at the age of 3 years to at the level of the occlusal plane at 9 years to above the occlusal plane in the adult group.

In the present study, the distances were measured from the internal oblique ridge to the posterior border of the ramus at the occlusal line (Table 37, p 146). We were unable to trace results for the same parameter in the available literature for the purpose of comparison. Other studies measured the shortest width of the ramus between the anterior and posterior border of the ramus, which may easy to do theoretically but it is practically more difficult to obtain and reproduce.

There is very strong genetic involvement and because the inferior alveolar nerve forms before the mandible that may result in a wide variation the shape and the position of mandibular foramen. A genetic factor is most likely to affect the development of the condylar notch.

Overall the present study indicated there were no significant differences between the right and left sides in each of the four populations with regard to all distances between the mandibular foramen and related landmarks. However, the fact that so many studies have been conducted on this foramen indicates its clinical importance, especially with respect to inferior dental block injections. Also there were no significant differences with regard to all distances between the mandibular foramen and related landmarks on both sides where comparisons were made between the different populations only some distances which were significantly different as exhibited in (Tables 42 - 53), which were mainly not clinically relevant.

Overall, there were no significant differences with regard to all distances related to the mandibular foramen region on the right and left sides where ipsilateral comparisons were made between the different populations.

The symmetry of the location of the foramina between sides highlights the ability to determine the location of the second side based on knowledge of the location of the first side. Overall, symmetry of the positions of four maxillofacial foramina in relation to specific anatomical landmarks in human skulls from each of the four populations may due to the statistical tests utilised.

2. Inter-Population Comparisons between the Right and Left Sides in Each Population Group

Distances Related to the Supraorbital Foramen: In the present study, the mean distances between the right and left supraorbital foramina were similar with no significant differences between all populations except that there were statistically significant differences between the British and Hylam populations and between the Indian and British populations. These statistical significances were considered not clinically relevant except between the between the British and Hylam where the difference was more than 5 mm.

With regard to the distance between the foramen and the midline, there were no significant differences between the ipsilateral distances on the right and left sides between all populations, except that there were significant differences on the left side between the Hokien and Hylam and between the Hylam and British populations.

With regard to the distance between the foramen to the temporal crest, there were no significant differences on the right and left sides between the Hokien and Hylam and between Indian and British populations, whereas, there were significant differences between the Hokien and Indian, Hokien and British, Hylam and Indian and Hylam and British populations on the right and on the left side. The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant because the difference was less than 3 mm except between the between the Hokien and British and Hylam and British populations on the right and between the Hylam and British populations on the left side where the difference was more around 4 mm. Related to the distance between the foramen and the supraorbital rim, there were no significant differences between the ipsilateral distances on the right and left sides between all populations. Overall, there were no clinically significant differences with regard to all distances related to the supraorbital foramen region on the right and left sides where comparisons are made between the different populations. However, in other study (Ashwini *et al.*, 2012) the position of the supraorbital foramen was not constant and varies between different populations of different regions.

The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant.

Distances Related to the Infraorbital Foramen: In the present study, the mean distances between the right and left infraorbital foramina in all populations were found to range between 50.00 mm to 53.17 mm (Table 42, p 151) and corresponded to data given by both Song *et al*. (2007) and Gupta (2008). The mean of this distance was similar with no significant differences where comparisons were made between the different populations, except that there were significant differences between the Hokien versus Hylam and Hylam versus Indian and Hylam versus British populations. These statistical significances were considered as not clinically relevant because the differences were less than 3 mm except between the between Hylam and British populations where the difference was 3.17 mm.

Overall, the statistical significance differences in cases of inter-population comparison between different populations (Table 42 - 48, pp. 151 - 154) were mainly not clinically relevant because the differences were mainly less than 3 mm except between the Hokien verses Indian and Hylam verses Indian populations on the right side and on the left side between the Hylam verses Indian populations with regard to vertical distance from the infraorbital to the supraorbital foramina where the difference were 3- 4 mm.

Distances Related to the Mental Foramen: The mental foramen was reported to be positioned approximately one quarter along the distance between the mandibular symphysis menti and the posterior border of the ramus in all four populations and were similar to the findings given by (Tebo & Telford, 1950; Mbajiorgu *et al.*, 1998; Smajilagic & Dilberovic, 2004; Souaga *et al.*, 2004). However, they differ from other study (Yesilyurt *et al.*, 2008) in which the mental foramen was situated at 1:3.5 of this distance. Although, this study used the same method as the present study, no explanation can be given other than the difference in population's studies. The relative position of the mental foramen in relation to the mandibular symphysis and the posterior border of the ramus were reported symmetrically in the previous mentioned studies and also in the present study, but the relative position of the foramen may be influenced by factors such as age, mesiodistal tooth size, attrition of the proximal surface and genetic factors.

The mandibular size was obtained from the summation of the distances from the most medial point of the mental foramen to the symphysis menti and the distance to the posterior border of the ramus. In the present study, the mean of the mandibular sizes were similar with no significant differences between the size of the mandible on the right and left sides in each of the four populations except the British population. Though there was a mathematical significant difference between the right and left sides of the mandible in the British population, this should be considered as "normal", anatomical asymmetry without clinical significant. Also there were no significant differences on the right and left sides where comparisons were made between the different populations. On the right side, the only groups which were significantly different were the Hokien versus Hylam and Indian versus Hylam. On the left side, the only groups were the Hylam versus Indian and British versus Indian populations.

The relative positions of the mental foramen on both sides were given in two ways, either by the ratio of the distance between the most medial point of the mental foramen and the symphysis menti to the distance between the most medial point of the mental foramen and the symphysis menti plus, the distance between the most medial point of the mental foramen and the posterior border of the ramus or by the ratio of the distance between the most medial point of the mental foramen and the posterior border of the ramus to the distance between the most medial point of the mental foramen and the symphysis menti plus the distance between the most medial point of the mental foramen and the posterior border of the ramus. The results showed that the relative position of the mental foramen was similar in either of the calculated ratios on both sides in the Hokien, Hylam and Indian populations. These differenced from the British ratios, indicates that in these three populations, the relative position of the mental foramen was more posterior than in the British population.

Overall, there were no clinically significant differences with regard to all distances related to the mental foramen region on the right and left sides where ipsilateral comparisons were made between the different populations.

The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant (Table 46, p 155) because the differences were mainly less than 3 mm.

Distances Related to the Mandibular Foramen: Overall, there were no clinically significant differences with regard to all distances related to the mandibular foramen region on the right and left sides where ipsilateral comparisons were made between the different populations.

The statistical significance differences in cases of inter-population comparison between different populations (Table 47 – 53, pp. 156 - 159) were mainly not clinically relevant because the differences were mainly less than 3 mm except between Hylam verses Indian and Hylam verses British populations on the left side with regard to the distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line where the difference were 3.20 mm and 3.06 mm respectively.

3. Intra-Population Comparisons of Foraminal Positions With Respect to Age in Each of the Four Populations

Each population was divided, based on Brothwell's chart, into four age groups, group 1 (17-25), group 2 (26-35), group 3 (36-45) and group 4 (> 45 years).

With a very few exceptions (Table 52 to Table 79) with respect to the four age groups, in each population, there were no significant statistical differences between distances related to the supraorbital, infraorbital, mental or mandibular foramen.

The present study includes the use of Chinese dry skulls of known age. The ages were recorded from gravestone records at the time of acquisition. Several other studies also reported using dry skulls of known age (McKinstry, 1987; Santini & Land, 1990; Karakas *et al.*, 2003; Apinhasmit *et al.*, 2006; Prabodha & Nanayakkara, 2006). Of these studies, McKinstry (1987), Apinhasmit *et al* (2006) and Prabodha & Nanayakkara (2006) gave no indication how these ages had been determined. Karakas et al.(2003) said they were assessed by the state of the dentition but did not say whether this was from eruption and/or tooth wear. Santini & Land (1990) used the same skulls as the present study. Both the present study and that of McKinstry (1987) found that foraminal position did not change with age, unlike Prabodha & Nanayakkara (2006) who said there was a change in the position of the mental foramen with age and Karakas *et al.*(2003) who considered the variation in the position of the supraorbital and infraorbital foramina could be a result of factors such as age. Interestingly, the papers by McKinstry (1987), Santini & Land (1990) deal with skulls of known, not assessed age whereas, Karakas *et al.*(2003) assessed the ages of their skulls.

The following other studies did not used dry skulls; they used either radiography or cadavers. They also concluded that there was no significant difference of measured distances of stated foramina with respect to age of patients (Afsar *et al.*, 1998; Angel *et al.*, 2011). However, another study revealed that the mental foramen moved inferiorly and posteriorly with advancing age (AL-Khateeb *et al.*, 2007).

Overall, statistically the position of the four foramina in all populations was not changed significantly with the age.

3D Laser Scanning Method Using 3D Laser Scanning

In the present study all distances between all four foramina and their relative landmarks were discussed under the results that have been obtained by electronic digital calliper method using electronic digital calliper with the exception of the distance between the mental foramen to the inferior border of the mandible because this distance was not measured by electronic digital calliper method due to the limitations mentioned above.

In the present study, the mean distances between the mental foramina to the inferior border of the mandible using 3D laser Scanning on both sides in all populations ranged between 13.86 mm to 15.76 mm (Table 90, p 183) and were approximately similar to the results of studies by Matsuda (1927), Chung *et al.* (1995), Lopes *et al.* (2010), Budhiraja *et al.* (2013) and 12 other studies (see the literature review). However, they differ from previous studies by Neiva *et al.* (2004), Prabodha & Nanayakkara (2006),Yesilyurt *et al.* (2008), Oliveira *et al*. (2009), Sankar *et al.* (2011), Agarwal & Gupta (2011), Parmar *et al*. (2013) and Smith et al. (2010). The difference may be because different “points” were used in the different studies.

In the present study, the mean distances between the mental foramen and the inferior border of the mandible were similar with no significant differences on the right and left sides in each of the four populations. Also there were no significant differences in this distance where comparisons were made between the different populations with the exception that on the right side, there were significant differences were between the Hokien versus Indian, Hylam versus Indian and Hylam versus British populations. However, on the left side there were significant differences between the Hokien versus Hylam, Hokien versus Indian, Hylam versus Indian and Hylam versus British populations. These statistical significances were considered as false positive and not clinically relevant.

In the present study, there was bilateral symmetry on both sides in all distances related to the four foramen regions in each of the four populations, the statistical significance differences were considered as false positives.

Also overall, there were no significant differences with regard to all distances related to the four foraminal regions on the right and left sides when comparisons are made between the different populations. The statistical significance differences in cases of intra-population and inter-population comparisons were mainly not clinically relevant.

1. Intra-Population Comparisons between Right and Left Sides in Each Population Groups

Distances Related to Supraorbital Foramen: There were no significant differences with regard to all distances between the supraorbital foramen and related landmarks when comparisons were made between the right and left sides in each of the four populations except the Hokien population where there was a significant difference between the right and left sides with regard to the distance from the foramen to the temporal crest as exhibited in Table 80 and Table 81 (p179) which was not clinically relevant because the difference was less than 1 mm.

Overall, there were no significant differences with regard to all distances related to the supraorbital foramen region when comparisons were made between the right and left sides in each of the four populations.

Distances Related to Infraorbital Foramen: There were no significant differences with regard to all distances between the infraorbital foramen and related landmarks when comparisons were made between the right and left sides in each of the four populations except the Hokien population where there was a significant difference between the right and left sides with regard to the distance from the foramen to midline at the level of the supraorbital foramen and to the facial midline as exhibited in Table 82 – Table 87, (pp. 180 - 182) which was not clinically relevant because the difference was about 1 mm.

Overall, there were no significant differences with regard to all distances related to the infraorbital foramen region when comparisons were made between the right and left sides in each of the four populations.

Distances Related to Mental Foramen: As there were no significant differences with regard to all distances between the mental foramen and related landmarks when comparisons were made between the right and left sides in each of the four populations (Table 88 –Table 90, p 182), it was concluded that bilateral symmetry existed.

Distances Related to Mandibular Foramen: There were no significant differences with regard to all distances between the mandibular foramen and related landmarks when comparisons were made between the right and left sides in each of the four populations except the Hylam population with regard to the distances from the mandibular foramen to posterior border of the ramus at the same level and at occlusal line where there was a significant difference between the right and left sides in each of the four populations as exhibited in Table 91 to Table 98 (pp. 183 - 185) which was not clinically relevant because the difference was less than 1 mm.

Overall, there were no significant differences with regard to all distances related to the mandibular foramen region when comparisons were made between the right and left sides in each of the four populations.

2. Inter-Population Comparisons between ipsilateral Distances in Four Population Groups:

Distances Related to Supraorbital Foramen: There were no significant differences with regard to all distances between the supraorbital foramen and related landmarks on both sides when comparisons were made between the different populations. Some distances were significantly different as exhibited in Table 99 and Table 100 (pp. 186 - 187) but were not considered clinically relevant. Overall, there were no significant differences with regard to all distances related to the supraorbital foramen region on the right and left sides where ipsilateral comparisons were made between the different populations.

The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant because the difference was less than 3 mm except between the Hylam versus British and Indian versus British populations with regard to the distances between the right and the left supraorbital foramina where the differences were 5.9 mm and 3.07 mm respectively and the Hokien versus British and Hylam versus British populations on the right and left sides where the differences were 3.27 – 4.34 mm. Again the statistical significance differences in cases of inter-population comparison were not considered to be of clinical relevance.

Distances Related to Infraorbital Foramen: There were no significant differences with regard to all distances between the infraorbital foramen and related landmarks on both sides when comparisons were made between the different populations. Some distances were significantly different as exhibited in Table 101 – Table 104 (pp. 188 - 191), but were not considered to be of clinical relevance. Overall, there were no significant differences with regard to all distances related to the infraorbital foramen region on the right and left sides where ipsilateral comparisons were made between the different populations. The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant because the differences were less than 3 mm except between the Hylam versus British populations with regard to the distances between the right and the left infraorbital foramina where the difference was 3.2 mm and the Hokien versus Indian and Hylam versus Indian populations on the right and left sides with regard to the vertical distance from the supraorbital foramen to the infraorbital foramen where the differences were 3.67 – 4.45 mm.

Distances Related to Mental Foramen: There were no significant differences with regard to all distances between the mental foramen and related landmarks on both sides when comparisons were made between the different populations. Some distances which were significantly different as exhibited in Table 105 – Table 107 (pp. 192 - 194), which was mainly not clinically relevant. Overall, there were no significant differences with regard to all distances related to the mental foramen region on the right and left sides when ipsilateral comparisons were made between the different populations. The statistical significance differences were mainly not clinically relevant with regard to the distances of the mental foramen to the posterior border of the mandible.

Distances Related to Mandibular Foramen: There were no significant differences with regard to all distances between the mandibular foramen and related landmarks on both sides where comparisons were made between the different populations. Some distances were significantly different as exhibited in Table 108 - Table 111 (pp. 195 - 198) which was not clinically relevant. Overall, there were no significant differences with regard to all distances related to the mandibular foramen region on the right and left sides where ipsilateral comparisons were made between the different populations. The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant because the difference was less than 3 mm except between the Hokien versus Indian on the left side and Hylam versus Indian populations on the right and left sides with regard to the distance from the posterior border of the ramus to the internal oblique ridge at the level of the occlusal line where the difference was 3.30 – 3.46 mm, and the Hokien versus Indian populations on the left sides with regard to the distance from the posterior border of the ramus to the external oblique ridge at the level of the occlusal line where the difference was 3.21 mm. The statistical significance differences in cases of inter-population comparison were mainly not clinically relevant.

Overall, there were no significant differences where ipsilateral comparisons were carried out between four populations with regard to all distances related to the four maxillofacial foramina. Where there were statistically significant differences, these tended to be not clinically relevant and this finding concurred with a previous study (Hayward *et al.*, 1977) on Asiatic, black and white Americans (USA). It differs from another study (Cutright *et al.*, 2003) which concluded that there were small but statistically significant differences in regard to the position of the mental foramen between black and white populations. (Kimura (1977) also found a difference in position of the supraorbital foramen between white, black Americans, Indian (sub-continental) and Japanese population groups. The morphology of the skulls of the population groups that were studied tended to show differences i.e. Chinese skulls were initially described as larger than Indian skulls but the result of measurements revealed that there were no significant differences between the populations. It is interesting to note that Birker (1977) as cited by (Wilkinson, 2004) was of the opinion that the facial soft tissues vary more than the bony elements of the skulls in different population groups.

Results of the Comparisons between Electronic Digital Calliper and 3D Laser Scanning Measurements of Ipsilateral Distances Related to Four Foramina in each of the Four Population

A comparison of the electronic digital calliper and 3D scanning methods were made using the Bland-Altman statistical approach. This method was preferred to conventional correlation statistics for the reason previously discussed on page 234. Very good agreements between the electronic calliper and the scanning measurements were obtained for measurements relating to the distance between right supraorbital to the left supraorbital foramina, the right to the left fronto-maxillary sutures, the right infraorbital to the left infraorbital foramina, the infraorbital to the supraorbital foramen (vertically), the most medial point of the mental foramen and the posterior border of the ramus and the most anterior inferior border of the mandibular foramen to the lowest point on the condylar notch. Less, but never the less, overall good agreements were obtained for distances between the supraorbital foramen to the midline, the level of the infraorbital foramen to the midline at the level of the supraorbital foramen, the level of the infraorbital foramen to the anterior nasal spine, the mental foramen to the symphysis menti, and the mandibular foramen to the internal oblique ridge at the occlusal line, the internal oblique ridge to the posterior border of the ramus at the occlusal line and the external oblique ridge to the posterior border of the ramus at the occlusal line. Only moderate agreement was obtained for distances between the infraorbital foramen to infraorbital rim and the mandibular foramen to the posterior border of the ramus at the same level. Overall low or very low agreements were obtained for distances between, the most medial point of the supraorbital foramen and the temporal crest, the mandibular foramen to inferior border of the mandible and the mandibular foramen to posterior border of the ramus at occlusal line.

Based on the current results, very good and good agreements were shown for distances between well-defined points or between two clearly identifiable anatomical landmarks. Were only moderate agreement was obtained, these were for relatively short distances or between foramina and the non-well defined landmarks.

Park *et al.* (2006), who compared cranial mesurement from lambda to 26 landmarks using callipers with those taken by 3D laser scanning. There was no significant difference between the two measuring methods, though the 3D laser scanning method tended to give a slightly lower reading. He concluded that overall, the 3D laser scanning method can replace the conventional electronic calliper measuring method in craniometry. In a similar study (Periago *et al.*, 2008) which compared measurements between cone beam computed tomographic and direct anatomic measurements, the mean intraclass correlation coefficient of skull measurements was significantly higher than the mean intraclass correlation coefficient for cone beam computed tomographic measurements. The study concluded that this statistical significance probably did not translate into clinical relevance. Most can be considered to be sufficiently clinically accurate for craniofacial analyses. Peker *et al*. (2009) compared measurements taken from conventional and panoramic radiographs and measurements taken directly from skull. He found a strong positive correlation between these methods as did Kositbowornchai *et al*.(2007) who reported a high concordance between the measured distances in panoramic radiography and dry mandibles.

In the current study, low or very low agreements were obtained for distances between foramina and curved anatomical landmarks such as the temporal crest and inferior border of the mandible. These measurements were affected by the horizontal plane, whereas, other distances between the mandibular foramen to inferior border of the mandible were affected severely by the curvature of the inferior border of the mandible. The measurement from the mandibular foramen to the posterior border of the ramus (taken along the extension of the occlusal plane) was affected dramatically by the position of the occlusal plane. A similar low agreement was reported in a previous study (Dutra *et al.*, 2007) where there was lower agreement between the actual mandible measurements and those obtained by radiographic assessment. Agreement between anatomic and radiographic measurements improved remarkably after standard correction for magnification was undertaken.

The present study revealed that the 3D laser scanning method is a very useful method for craniometry as it provides data as accurate as calliper measurements, and therefore can be recommended as an alternative measurement method. Excellent intra and inter-reliabilities were obtained with 3D laser scanning with the exceptions of four data which depend on the interpretation of the position of the occlusal line.

As well as being an excellent measuring tool, 3D laser scanning can be adapted for teaching purpose such as anatomy as it can show anatomical details in three dimensions. With respect to medical or surgical intervention, it can be of extreme value, particularly in specific areas, as it allows focusing on distinct anatomical structures such as nerves or blood vessels. Because it allows identification of the relationship between different structures, from superficial to deep, and from any angle, identification of structures that may be at risk during procedures such a dental local anaesthesia can be highlighted, allowing students to practice when learning injections procedures. It is an excellent tool in the field of anthropology not only because of its measurement potential, but also in that it is portable, can be taken ‘on site’ and records kept and distributed, especially in situations where it would be impossible to remove and store skulls or other anatomical structures.

Chapter 10
Conclusion

Overall conclusions

There was no clinically significant difference in measurements relating to the position of the supraorbital, infraorbital, mental and mandibular foramina in any of the four populations used in the present study.

Comparison of the electronic digital calliper and 3D scanning methods showed there was overall no significant difference between the two methods. However, the 3D laser scanning afford distant advantages in obtaining more sophisticated data, such as “curvature distances” and is considered the method of choice for future studies.

Main results:

The supraorbital foramina were situated approximately half way along the line from the midline to the temporal crest in all four populations (Table 14, p 104).

The distance between the right and the left infraorbital foramina was represented approximately half way along the width of the skull, which represented by the distance between the right and the left fronto-zygomatico sutures (Table 14 & 15, p 104).

The mental foramen was situated approximately one quarter along the line between the mandibular symphysis menti and the posterior border of the ramus.

The position of the supraorbital, infraorbital, mental and mandibular foramina show bilateral symmetry in each skull of the four populations with regard to age and sides.

There were no significant differences between ipsilateral measurements from each foramen to stated anatomical landmarks in any of the four population groups.

There were no significant differences between ipsilateral measurements from each foramen to stated anatomical landmarks in each of four age groups in any of the four population groups.

There was no correlation between the degree of obtuseness of the mandibular angle and the ipsilateral measurement from the mental foramen to the posterior border of the mandible, on either side of the skulls in any of the population groups.

The study showed overall good agreements between the electronic digital calliper and 3D laser scanning methods for each foramen to stated anatomical landmarks in the four population groups. It was concluded that either of the two methods could be used interchangeably, though for reason mentioned previously, 3D scanning was considered the method of choice for future studies.

Chapter 11
Future Work

This work will be extended to include more populations such as Arabic and North African populations because there are only a few studies relating to these.

Geometric morphometric methods on the 3D laser scanned skulls of the four populations used in the present study will be undertaken. Geometric morphometric measurements follow the curvature of the skulls and so differ from data obtained from electric digital calliper or the ruler tool measurements which measure the shortest distances between two points.

Nowadays, unfortunately there are many incidents of reported massacres particularly in North Africa (Libya) or in Middle East (Syria). 3D laser scanning techniques provide a means of recording data from such incidents as the apparatus is relatively inexpensive, portable and allows data to be recovered and sent virtually anywhere.

The present data can be used to improve clinical local anaesthetic nerve block procedures such as the Vazirani-Akinosi closed-mouth technique and Gow-Gates method, by providing robust measurements.

3D laser scanning is used for facial anthropology and forensic facial reconstruction in the Centre for Anatomy and Human Identification, College of Life Sciences, University of Dundee. In Glasgow an interactive head and neck anatomy package was developed to enable students to dissect the head and neck “virtually” (Forgie, 2013).

I intend to attend courses on the use of 3D laser scanning in both these centres and to take the technology back to my own university where they will be put into operation in the dental school.

Chapter 12

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Appendix

Raw data and data analysis, where mentioned in this thesis, are to be found on a CD accompanying this work.