SEX IDENTIFICATION BY MAXILLARY SINUS MEASUREMENTS USING MDCT: A STUDY AMONG MALAY ADULTS IN HOSPITAL UNIVERSITI SAINS MALAYSIA (HUSM)

By:

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SEX IDENTIFICATION BY MAXILLARY SINUS MEASUREMENTS USING MDCT: A STUDY AMONG MALAY ADULTS IN HOSPITAL UNIVERSITI SAINS MALAYSIA (HUSM).

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Introduction: Sex identification of the skeletal remains is one of the concerns in forensic medicine, apart from age, stature and race. Since most bones that are conventionally used for sex determination are often recovered either in a fragmented or incomplete state, it is necessary to use denser bones that are often recovered intact, for example maxillary sinus. Nowadays, the introduction of Multidetector Computed Tomography (MDCT) with thin axial sections, sagittal and coronal reformatted images has allowed a more accurate assessment of this structure. Apart from the difficulty in obtaining a complete skeleton for sex identification, the variable parameters measured are population specific. Thus, the aim of this study is to evaluate the accuracy of maxillary sinus measurements by MDCT in identification of sex among adult Malay population attending Hospital Universiti Sains Malaysia (HUSM).

Objective: To determine the sex by measurement of maxillary sinus dimensions using MDCT in Malay adults.

Patients and Methods: This was a cross-sectional study done at the Department of Radiology, HUSM from November 2011 until November 2014. MDCT scan study for head trauma of 140 adult Malay patients aged between 18 to 89 years were reviewed. Ten maxillary sinus dimensions were measured and subjected for descriptive and univariate/multivariate discriminant function analysis. Data entry and analysis were performed using Statistical Package for Social Sciences (SPSS version 22) software programme.

Results: Our results showed statistically significant difference of the mean value of maxillary sinus dimensions in males and females. The mean values for males were consistently higher as compared to females. Eight out of 10 measurement parameters taken in this study were significant for sex identification except for total distance across both sinuses and intermaxillary distance. The accuracy of sex determination by maxillary sinus dimensions using univariate discriminant function analysis is ranging from 61.5% to 67.9%. Our study also showed that combination of two or more measurement parameters using multivariate discriminant function analysis has increased the accuracy in sex identification by maxillary sinus dimensions with the highest accuracy of 70.7% for the right maxillary sinus.

Conclusion: Measurement of maxillary sinus dimensions by multidetector computed tomography (MDCT) is useful for gender differentiation among Malay adults and fairly accurate for sex identification in Forensic Medicine.

Dr Juhara Haron: Supervisor

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ABBREVIATIONS AND TERMS

HUSM	- Hospital Universiti Sains Malaysia
MDCT scan	- Multi-detector Computed Tomography scan
PACS	- Picture Archiving and Communication System
DICOM	- Digital Imaging and Communications in Medicine
AP	- Anteroposterior
CC	- Cephalocaudal
CI	- Confident Interval
SD	- Standard Deviation
D	- Demarking point
SPSS	- Statistical Package for Social Sciences, later Statistical Product and Service Solution
VIFM	- Victorian Institute of Forensic Medicine
WHO	- World Health Organization

ABSTRAK

Bahasa Malaysia

Tajuk:

Penentuan jantina berdasarkan pengukuran rongga maksilari menggunakan MDCT: Satu kajian di kalangan Melayu dewasa di HUSM.

Latarbelakang:

Penentuan jantina daripada tinggalan rangka merupakan salah satu aspek yang dititikberatkan dalam Perubatan Forensik, selain daripada umur, ketinggian dan bangsa. Oleh kerana kebanyakan tulang yang kebiasaannya digunakan untuk penentuan jantina selalunya dijumpai dalam keadaan tidak sempurna atau pecah, penggunaan tulang yang lebih keras yang selalu dijumpai dalam keadaan sempurna sebagai contohnya rongga maksilari sangat diperlukan. Kebelakangan ini, kewujudan Multidetector Computed Tomography (MDCT) dengan imej nipis yang diformatkan kepada keratan rentas 'axial', 'sagittal' dan 'coronal' membolehkan pengukuran yang lebih tepat dilakukan ke atas struktur ini.

Namun begitu, selain daripada kesukaran mendapatkan sampel tulang yang lengkap untuk penentuan jantina, masalah lain yang sering timbul adalah parameter yang diukur kebiasaannya adalah spesifik kepada sesuatu populasi sahaja. Oleh sebab itu, matlamat kajian ini adalah untuk menilai tahap ketepatan pengukuran rongga maksilari menggunakan MDCT dalam penentuan jantina di

kalangan populasi Melayu dewasa yang datang ke HUSM, disebabkan tiada data yang pernah di keluarkan khusus kepada populasi ini.

Objektif:

Untuk menentukan jantina bagi populasi Melayu dewasa di HUSM berdasarkan pengukuran rongga maksilari menggunakan MDCT.

Metodologi:

Ini merupakan satu kajian keratan rentas yang dijalankan di Jabatan Radiologi HUSM, dari November 2011 sehingga November 2014. Imbasan MDCT kepala yang dijalankan untuk kes bagi pesakit berumur 18 hingga 89 tahun telah dinilai. Ukuran bagi 10 dimensi rongga maksilari telah diambil dan dianalisa menggunakan analisis 'univariate' dan 'multivariate disciminant function'.

Pengisian dan analisis data telah dilakukan menggunakan program Statistical Package for Social Sciences (SPSS) versi 22.

Keputusan:

Keputusan menunjukkan terdapat perbezaan yang signifikan pada nilai min ukuran rongga maksilari lelaki dan perempuan. Nilai min bagi lelaki secara konsisten lebih tinggi berbanding perempuan. Lapan daripada sepuluh ukuran parameter yang diambil untuk kajian ini adalah signifikan untuk penentuan jantina kecuali jarak keseluruhan merentasi kedua-dua rongga maksilari dan jarak antara dua rongga maksilari. Tahap ketepatan penentuan jantina berdasarkan pengukuran rongga maksilari menggunakan analisis 'univariate discriminant function' adalah berkadaran daripada 61.4% hingga 67.9%. Selain itu, kajian ini juga menunjukkan kombinasi dua atau lebih ukuran diameter menggunakan analisis 'multivariate discriminant function' telah meningkatkan tahap ketepatan dalam penentuan jantina melalui pengukuran rongga maksilari dengan tahap ketepatan tertinggi sehingga 70.7% bagi rongga maksilari kanan.

Kesimpulan:

Pengukuran rongga maksilari menggunakan MDCT mampu menunjukkan perbezaan antara jantina dan agak tepat dalam penentuan jantina bagi bidang Perubatan Forensik.

ABSTRACT

English

Title:

Sex identification by maxillary sinus measurements using MDCT: A study among Malay adults in Hospital Universiti Sains Malaysia (HUSM).

Background:

Sex identification of the skeletal remains is one of the concerns in forensic medicine, apart from age, stature and race. Since most bones that are conventionally used for sex determination are often recovered either in a fragmented or incomplete state, it is necessary to use denser bones that are often recovered intact, for example maxillary sinus. Nowadays, the introduction of Multidetector Computed Tomography (MDCT) with thin axial sections, sagittal and coronal reformatted images has allowed a more accurate assessment of this structure.

Apart from the difficulty in obtaining a complete skeleton for sex identification, the variable parameters measured are population specific. Thus, the aim of this study is to evaluate the accuracy of maxillary sinus measurements by MDCT in identification of sex among adult Malay population attending Hospital Universiti Sains Malaysia (HUSM).

Objective:

To determine the sex by measurement of maxillary sinus dimensions using MDCT in Malay adults.

Methodology:

This was a cross-sectional study done at the Department of Radiology, HUSM from November 2011 until November 2014. MDCT scan study for head trauma of 140 adult Malay patients aged between 18 to 89 years were reviewed. Ten maxillary sinus dimensions were measured and subjected for descriptive and univariate/multivariate discriminant function analysis. Data entry and analysis were performed using Statistical Package for Social Sciences (SPSS version 22) software programme.

Results:

Our results showed statistically significant difference of the mean value of maxillary sinus dimensions in males and females. The mean values for males were consistently higher as compared to females. Eight out of 10 measurement parameters taken in this study were significant for sex identification except for total distance across both sinuses and intermaxillary distance. The accuracy of sex determination by maxillary sinus dimensions using univariate discriminant function analysis is ranging from 61.5% to 67.9%. Our study also showed that combination of two or more measurement parameters using multivariate discriminant function

analysis has increased the accuracy in sex identification by maxillary sinus dimensions with the highest accuracy of 70.7% for the right maxillary sinus.

Conclusion:

Measurement of maxillary sinus dimensions by multidetector computed tomography (MDCT) is useful for gender differentiation among Malay adults and fairly accurate for sex identification in Forensic Medicine.

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1.0 INTRODUCTION

Identification of skeletal remains is one of the most difficult skills in anthropology and forensic medicine. Sex identification is one of the concerns, apart from age, stature and race.

The study of anthropometric characteristic is of fundamental importance to solve problems related to identification (Uthman *et al.*, 2011). The ability to determine sex from isolated and fragmented bones is of particular relevance and importance especially in cases where criminals mutilate their victims in attempt to make their identification difficult and also in mass disasters as bones are usually commingled, charred and fragmented (Asala, 2001, Kranioti, 2009).

Identification of sex can be accomplished using either morphologic (non-metric) or morphometric (statistical) methodologies (El-Najjar and Mc Williams, 1978). The morphological method (non-metric) is by direct assessment of the skeletal remains. This method can produces valuable results and guides assessment, however, it requires experienced scientist or researcher.

Morphometric or statistical method which involves measurement of the bones followed by metrical analysis is becoming more popular, as it is more objective and the measurement is reproducible for future use. On the other hand, it does not rely on the experience and level of expertise of the scientist or researcher (El-Najjar and Mc Williams, 1978).

Skeletal remains have long been used for sex identification as bones of the body are last to perish after death, next to enamel of teeth (Deshmukh and Devershi, 2006). Pelvis, cranium and bones of upper and lower limbs are example of bones in the body that demonstrate sexual differences or dimorphism. There are many previous studies done for the identification of sex using skeletal remains, for example skull (Ramsthaler *et al.*, 2010), radius and ulna (Celbis and Agritmis, 2006), patella (Dayal and Bidmos, 2005) and scapula (Di Vella *et al.*, 1994). The skull, pelvis and long bones such as femur are most commonly used as they provide more accurate assessment in sex identification or determination.

However, in explosions, criminal cases or mass disasters like aircraft crashes where human remains are found badly disfigured, fragmented or incomplete, sex identification has become more challenging. Thus, collecting a complete set of skeletal remains is not an easy task or almost impossible in such cases. Frequently, only bony fragments or damaged bones are available for assessment. The degree of expertise required to perform the analysis will increase when the skeletal remains are fragmented or incomplete (Pretorius *et al.*, 2006)

Radiography has been used in forensic pathology for the identification of human especially in cases where the body is decomposed, fragmented or burned

(Rainio *et al.*, 2001). It can provides valuable information for sex identification and assists in giving accurate dimensions for which certain formulae can be applied to determine sex (Di Vella *et al.*, 1994).

Apart from skeletal sample collection, another main problem in identification of sex using skeletal remains is the specificity of the measured variables or parameters to certain population and the wide variability in degree of sexual dimorphism between the populations of different ethnic groups. Sex determination based on metric characteristics is most precise when population specific standards are available (Schwartz, 1995; Barnes and Wescott, 2008) Therefore, establishment of a standard data which is specific to a certain population is needed.

It has been reported that denser bones such as maxillary sinus often recovered intact, although the skull and other bones maybe badly disfigured in victims who are incinerated (Lerno, 1983). Therefore, the maxillary sinus can be used for identification.

Nowadays, introduction of Multidetector Computed Tomography (MDCT) with thin axial sections, sagittal and coronal reformatted images has allowed a more accurate assessment of this structure (Amin and Hassan, 2012). Furthermore, the application of morphometric procedures to these radiological images adds a new perspective to this analysis (Di Vella *et al.*, 1994).

Few studies have been done in other countries to determine sex in certain population or ethnic group by maxillary sinus measurements using MDCT. Therefore, the aim of this study is to evaluate the accuracy of MDCT measurements of maxillary sinus in identification of sex among Malay adults in Hospital Universiti Sains Malaysia (HUSM). The results of this study will be a beneficial reference for baseline measurement of maxillary sinus dimensions since no previous study has been done before and no reference data or parameters available specifically for this population.

2.0 LITERATURE REVIEW

2.1 OVERVIEW

Radiology has been widely used in forensic medicine to visualise and document findings, in the living as well as the deceased. Diagnostic radiology was rapidly adopted by the forensic sciences, where radiographs were introduced as evidence in court to visualize a retained bullet in the leg of a victim of attempted murder, within a few years after the discovery of x-rays in 1895 (Thali *et al.*, 2002).

According to Rainio *et al.* (2001), radiography has been used in forensic pathology for the identification of human especially in cases where the body is decomposed, fragmented or burned. In general, determination of sex is not a difficult problem when a complete skeleton is available (Krogman and Iscan, 1986). However, this is not always the condition remains are found, for example in airplane crashes where bones can be broken into many pieces and only a small fragment may be available for identification.

It has been reported that denser bones such as maxillary sinus often recovered intact, although the skull and other bones maybe badly disfigured in victims who are incinerated (Lerno, 1983). Therefore, maxillary sinuses can be used for identification.

2.2 NORMAL ANATOMY AND PHYSIOLOGY OF MAXILLARY SINUS

2.2.1 Embryology and development

During the seventh to eighth gestational weeks, the lateral wall of the nasal capsule begins to form a series of ridges of mesenchymal tissue just superior to the palatal shelves. The first ridge, the maxilloturbinal, develops in the seventh week and gives rise to the inferior turbinates. During the eighth gestational week, a series of 5 to 6 ridges appear superior to the maxilloturbinal; through regression and fusion, these ridges form 3 to 5 ethmoturbinals. The first ethmoturbinal (sometimes referred to as the nasoturbinal) gives rise to agger nasi from its ascending portion and to the uncinate process from its descending portion. The remainder of the first ethmoturbinal regresses. The second ethmoturbinal forms the middle turbinate, the third forms the superior turbinate and the fourth and fifth ethmoturbinal fuse to form the supreme turbinate.

Whereas the ridges of the ethmoturbinals form structures, the spaces between the ethmoturbinals which is described as furrows, correspond to the spaces and clefts of the mature sinus drainage pathway. These furrows can be subdivided into primary or secondary. The first primary furrow gives rise to the infundibulum, hiatus semilunaris, middle meatus, and frontal recess. The second primary furrow corresponds to the superior meatus and the third primary furrow, the supreme meatus. Secondary furrows form supra and retrobullar recesses and the ethmoid air cells proper. The frontal recess, and subsequently the frontal sinus, likely develop as an expansion of the furrow between the first and second ethmoturbinals. In addition to the ridge and furrow development, a cartilaginous capsule surrounds the developing nasal cavity and has an important role in sinonasal development. Ultimately the cartilaginous structures resorb or ossify as the development progresses. Over the 2nd and 3rd trimesters the maxillary sinus continues to enlarge from the maxillary infundibulum. Figure 2.1 shows illustrative diagram of embryological development of face and figure 2.2 shows the sagittal diagram of developing lateral nasal cavity.

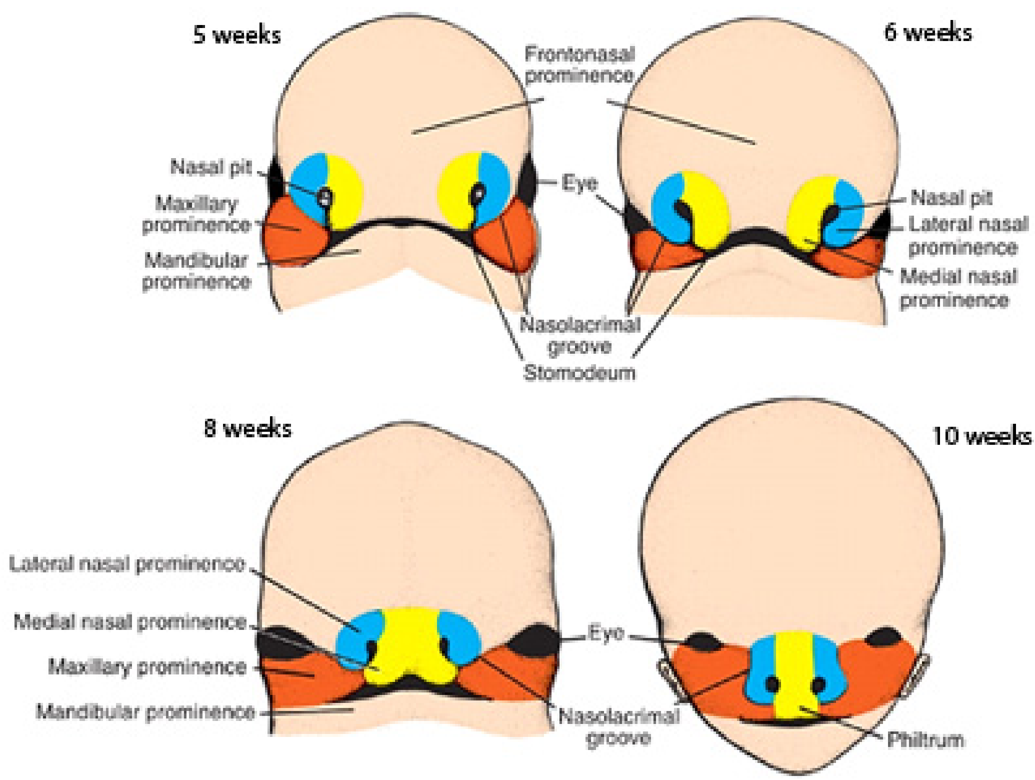

Figure 2.1: Embryological development of face.

(Source:https://web.duke.edu/anatomy/embryology/craniofacial/headEmbryoImage13.jpg).

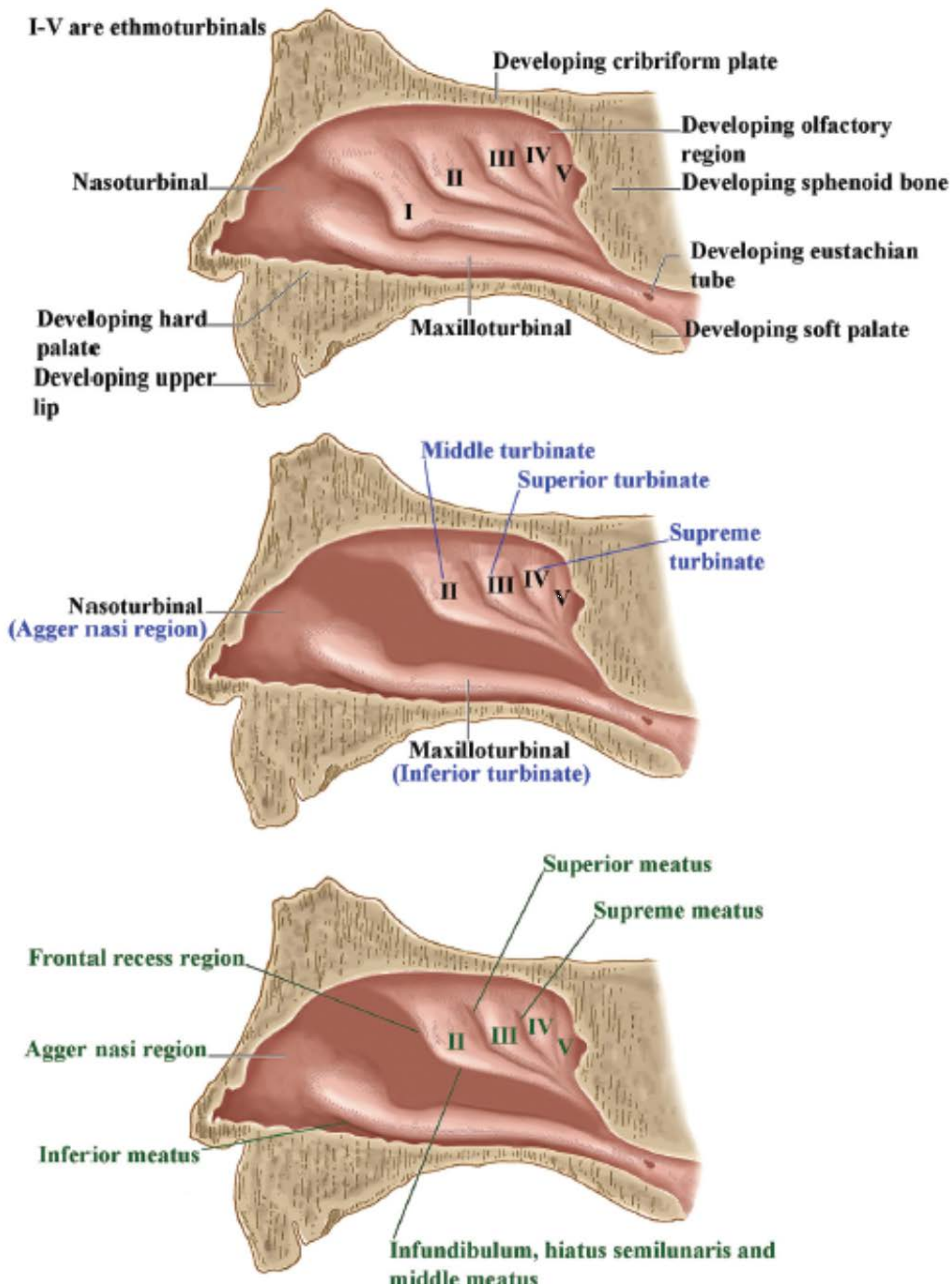

Figure 2.2: Sagittal diagram of developing nasal cavity showing the appearanceof the nasal turbinals and their eventual development into the nasal turbinates and meati (Som and Naidich, 2013).

The development of the ethmoturbinals is followed by the development of paranasal sinuses. The frontal, maxillary and ethmoid sinuses arise from evaginations of the lateral nasal wall, whereas the sphenoid sinuses arise from a posterior evagination of the nasal capsule. The sinuses begin to develop in the 3^{rd} fetal month and only the ethmoid and maxillary are present at birth.

The maxillary sinus begins as an outpouching of the lateral nasal wall at the tenth fetal week. It begins posterior to the descending portion of the first ethmoturbinal (the developing uncinate) and superior to the maxilloturbinal (the developing inferior turbinate). Nasal capsule resorption allows the maxillary sinus to enter into the developing maxillary process. The sinus is present at birth and expands in early childhood with the development of maxillary and teeth.

At birth, the maxillary sinus measures around 7 mm in anteroposterior depth, 4 mm in height and 2.7 mm in width (Barghouth *et al.*, 2002). The maxillary sinus continues to pneumatize most rapidly between ages 1 to 8 years, by which time the sinus extends laterally past the infraorbital canal, and inferiorly to the mid-inferior meatus. The floor of the maxillary sinus is initially oriented above the level of the nasal floor. Pneumatization reaches the level of the nasal floor following exfoliation and replacement of the primary dentition. In childhood, the roof of the maxillary sinus slopes inferolaterally, gradually assuming its more horizontal orientation seen in adulthood as pneumatization progresses.

At 16 years of age, the maxillary sinus reaches its adult dimensions, measuring 39 mm in depth, 36 mm in height and 27 mm in width (Duncavage and Becker, 2011). The size of the sinus is insignificant until the eruption of permanent dentition. The maxillary sinus enlarges variably and greatly by pneumatization until it reaches the adult size by eruption of the permanent teeth. Enlargement of the maxillary sinus is consequent to facial growth and its growth slows down with decline of facial growth during puberty but continues throughout life. Figure 2.3 and 2.4 show diagrams of maxillary sinus development.

The final size of the maxillary sinus varies between individuals and can be influenced by several factors. Hypoplasia of the maxillary sinus is relatively rare; it has been related to conditions such as severe infection, trauma, tumour, irradiation and syndromes affecting the first branchial arch.

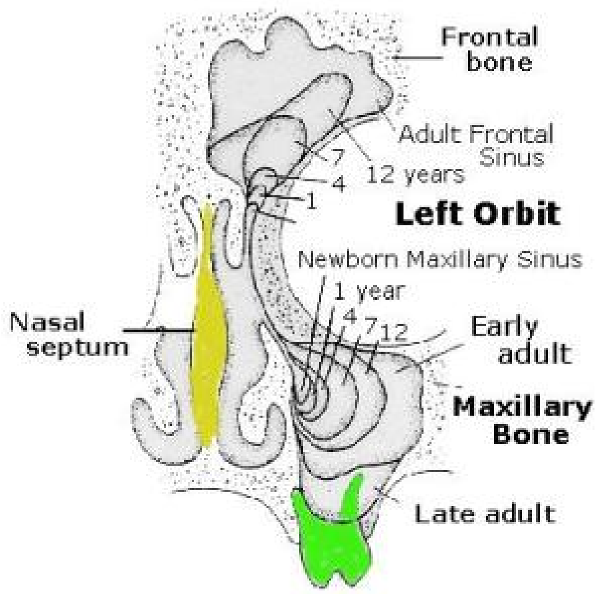

Figure 2.3: Development of maxillary sinus by age
(Source: http://entscholar.com/wp-content/uploads/2013/08/embryo.jpg)

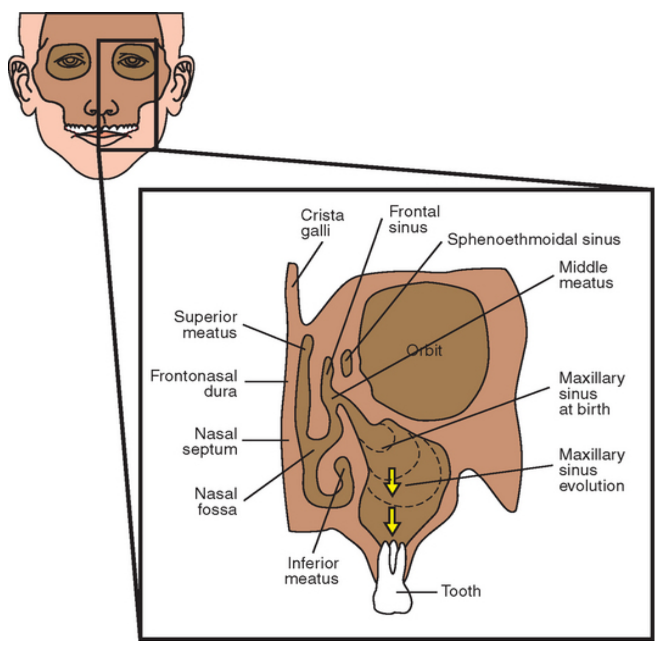

Figure 2.4: Maxillary sinus development in relation to facial growth and eruption of permanent dentition.
(Source:http://pocketdentistry.com/wpcontent/uploads/285/B9780323043731500459_f38-04-9780323043731.jpg).

2.2.2 Normal anatomy and physiology

The anatomy of the maxillary sinuses was first illustrated and described by Leonardo da Vinci in 1489 and later documented by the English anatomist Nathaniel Highmore in 1651. The maxillary sinus (or antrum of Highmore) lies within the body of the maxillary bone and is the largest of the paranasal sinuses, as well as the first to develop. It is a pyramid-shaped cavity with its base along the nasal wall and the apex pointing laterally towards the zygoma.

The medial wall consists of a thin bony plate composed of the maxilla, the inferior turbinate, the uncinate process, the perpendicular plate of the palatine bone and the lacrimal bone. The lateral apex of the sinus extends into the zygomatic process of the maxillary bone or into the zygoma. The roof of the maxillary sinus is formed by the bony orbital floor. The infraorbital nerve can often be seen as a ridge or groove along the roof of the sinus as the nerve passes from posterior to anterior direction. The floor of the maxillary sinus is formed by the alveolar and palatine processes of the maxillary and generally lies 1.0 cm to 1.2 cm below the level of the nasal cavity. The sinus floor usually has its most inferior point near the 1st molar region. The anterior wall of the maxillary sinus contains the infraorbital foramen located at the midsuperior portion. The canine fossa makes up the thinnest portion of the anterior wall and is located just above the canine tooth. The posterior wall of the sinus forms the anterior border of the pterygomaxillary fossa, which contains the internal maxillary artery, sphenopalatine ganglion, vidian nerve, greater palatine nerve and the second branch of the trigeminal nerve.

The average size of each maxillary sinus in adult is about 25 mm from side to side, 30 mm from front to back and 30 mm high with an average capacity of 15 ml (range from 9.5 ml to 20 ml) (Duncavage and Becker, 2011).

The maxillary sinus is lined with specialized cells (ciliated columnar epithelium) similar to those found in the respiratory tract. The lining secretes mucous that moved spirally and upward (against gravity) across the membrane towards the opening of the sinus, which is located on the anterosuperior wall, where secretions can drain into the nasal cavity.

The sinus drains into middle meatus of the nose. The opening through which the maxillary sinus communicates with the middle nasal meatus is termed ostium maxillare. It is about 3 to 6 mm in diameter and found in recess called hiatus semilunaris. The average capacity of the maxillary sinus is about 15ml.

The maxillary sinus functions are to lighten the skull, give resonance to the voice, warm the air we breathe and also moisten the nasal cavity. Figure 2.5 shows anatomy of the maxillary sinus and Figure 2.6 shows the maxillary sinus and surrounding bony structures.

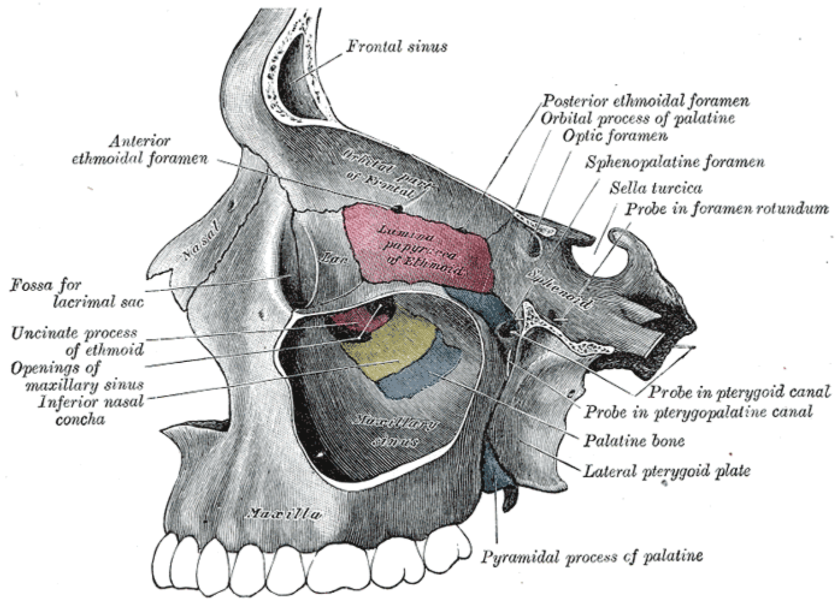

Figure 2.5: Anatomy of maxillary sinus.
Adapted from Gray's atlas of anatomy (Drake, 2008).

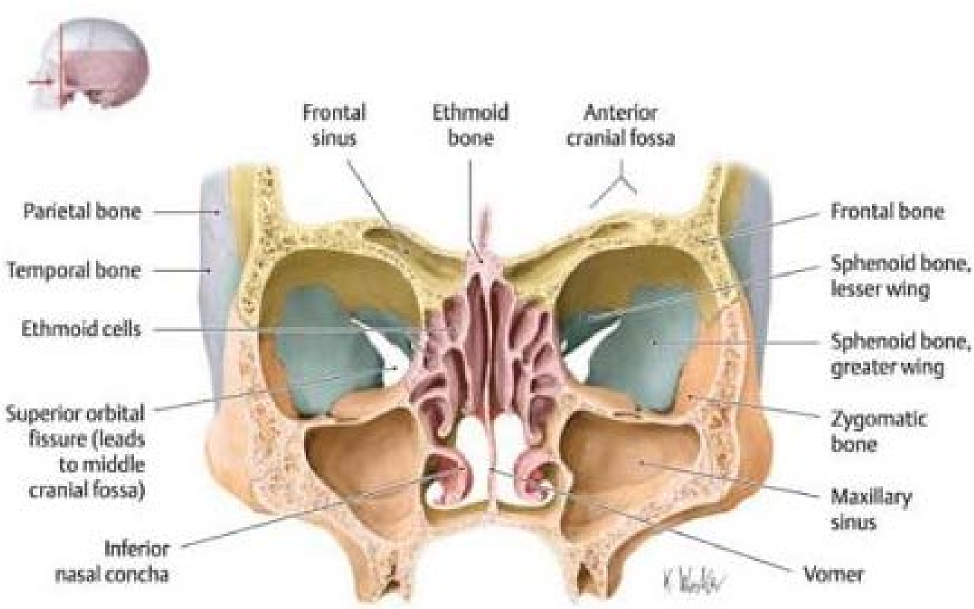

Figure 2.6: The maxillary sinuses and surrounding bony structures.
Adapted from Thieme atlas of anatomy: head and neuroanatomy (Schünke et al., 2007).

2.2.3 Anatomical variant

There are variation in size, shape and position of the sinus not only in different individuals but also in different sides of the same individual. The most common anatomic variation in the maxillary sinus region is the Infraorbital ethmoid air cells (Haller cell). This is an ethmoid cell that pneumatized along the medial roof of the maxillary sinus and inferomedial portion of lamina papyracea. These cells which are present in about 34% of patients, arise most commonly from the anterior ethmoid and frequently encroache on the infundibulum.

Another rare anatomic variation is hypoplasia or atelectasis of the maxillary sinus. The pathophysiology of this variation involves obstruction of the natural ostium by a lateralized uncinate process. This, in turns leads to a negative pressure environment with subsequent remodeling and involution of the bony maxillary walls. Although the atelectatic maxillary sinus is typically filled with thick mucus, the condition is often asymptomatic.

2.3 FORENSIC RADIOLOGY

2.3.1 Brief history, definition and role of Forensic Radiology

Forensic radiology, a subspecialty in radiology field, is the science of using x-rays to assist in investigating and gathering evidence for use in court of law, in civil and criminal cases. Besides radiography, the field has developed over the years to include CT scan, MRI and ultrasound technologies. The first time an X-ray was used for a forensic purpose was shortly after the technology was invented, according to the Victorian Institute of Forensic Medicine (VIFM). In 1895, Wilhelm Roentgen discovered X-rays and just a few months later, a bullet lodged in the leg of a gunshot victim was shown in an X-ray and the evidence was used in court to successfully prosecute the accused for attempted murder (Thali *et al.*, 2002).

Things have greatly improved since then and the scope of forensic radiology has increased. Forensic radiology is widely used in identification, age estimation and establishing a cause of death. Whether it is a single case or a mass fatality, plain film, dental and fluoroscopy have all been used to assist in this process. The use of radiography and other medical imaging specialties to aid in investigating civil and criminal matters has increased as investigators realize how radiologic technology can yield information that otherwise is unavailable (REYNOLDS, 2010).

2.3.2 Sex identification using skeletal remains

Sex identification is an important step towards establishing identity from unknown human remains. Identification of sex is more reliable if the complete skeleton is available, but in forensic cases human skeletal remains are often incomplete or damaged (Moneim *et al.*, 2008).

The need for identification may arise in cases of homicide, suicide, bomb blasts, terrorist's attacks, wars, airplane crashes, road and train accidents as well as natural mass disasters like tsunami, floods, and earth quakes (Krishan *et al.*, 2010). The accuracy of sex identification from unknown skeletal remains depends on the degree of sexual dimorphism exhibited by the skeleton (Moneim *et al.*, 2008).

Skeletal remains have long been used for sex identification as bones of the body are last to perish after death, next to enamel of teeth (Deshmukh and Devershi, 2006). There are many previous studies done for the identification of sex using skeletal remains; for example femur (İşcan and Shihai, 1995), skull (Ramsthaler *et al.*, 2010), radius and ulna (Celbis and Agritmis, 2006), patella (Dayal and Bidmos, 2005) and scapula (Di Vella *et al.*, 1994). Table 2.1 summarized the mean accuracy of sex identification by different skeletal remains according to various authors.

Table 2.1: Mean accuracy of sex identification by different skeletal remains according to various authors.

Authors (year)	Types of skeletal remains	Mean accuracy (%)
Di Vella *et al.* (1994)	Scapular	95.0%
Işcan and Shihai (1995)	Femur	94.9%
Dayal and Bidmos (2005)	Patella	85.0%
Celbis and Agritmis (2006)	Radius and ulna	96.0%
Ramsthaler *et al.* (2010)	Skull	96.0%

2.4 METHODS OF SKELETAL REMAINS MEASUREMENT

In the absence of DNA results, skeletal remains can be used to infer subject's sex via two methods, morphological (non-metrical) and morphometric (metrical) (Bašić *et al.*, 2013).

2.4.1 Morphological or non-metrical method

The morphological approach is based on the examination of the bones that show the strongest sexual dimorphism, principally the skull and the pelvis (Krogman and Iscan, 1986). However, this method is not always reliable, especially if the skull is fragmented or incomplete. Age can also affect the results, especially in elderly women, in which morphological characteristics of the skull tend to resemble those of men (Walker, 1995). Although morphological methods are very important for a preliminary sex assessment, they additionally rely on the experience of the examiner and are therefore rather subjective and unreliable (Bašić *et al.*, 2013).

2.4.2 Morphometric or metrical method

The second approach is based on morphometric analysis, which relies on the bone measurements. The main analytic approach is based on discriminant function analysis, which attempts to classify subjects into each of the sexes, by using either one or more bones (Vodanović *et al.*, 2007). This kind of analysis is a very important quantitative method for sex determination as it reduces the subjectivity of the examiner (Krogman and Iscan, 1986; Šlaus and Tomičić, 2005; Bruzek and Murail, 2006).

2.5 SEX IDENTIFICATION BY MAXILLARY SINUS DIMENSIONS

It has been reported that denser bones such as maxillary sinus remains intact, although the skull and other bones maybe badly disfigured in victims who are incinerated and therefore, maxillary sinuses can be used for identification (Lerno, 1983). There have been many studies done on maxillary sinus to determine sex in certain population or ethnic group.

The predictive role of the maxillary sinus in ethnic classification was established by a study done by Fernandes in 2004. It was found that dimensions of European sinuses were larger than those of Zulu sinuses. The discriminant analysis allowed for a very successful 90% ethnic prediction, while gender prediction was ultimately 79% (Fernandes, 2004a).

The result of a study done by Sidhu *et al.* (2014) showed that the maxillary sinus exhibited anatomic variability between genders. Lateral cephalogram of 50 subjects (25 males and 25 females) were taken and morphometric parameters of maxillary sinus were analyzed using AutoCAD 2010 software. A significant sex difference was found in relation to maxillary sinus area and perimeter with the mean area in males as 1.7261 cm^2 and mean perimeter as 5.2885 cm whereas, the mean area in females as 1.3424 cm^2 and mean perimeter as 4.3901 cm. Hence, showing males have a larger area and perimeter as compared to females (Sidhu *et al.*, 2014).

Studies have shown that CT scan was an excellent imaging modality used to evaluate the sinonasal cavities and provide an accurate assessment of paranasal sinuses, craniofacial bones and also extent of pneumatization of the sinuses (Wind and Zonneveld, 1989).

The discriminant analysis of a study done by Teke *et al.* in 2007 which measured width, length and height of maxillary sinuses in 127 adult patients using CT scan showed that the accuracy rate of maxillary sinuses measurements in identifying sex was 69.4% in females and 69.2% in males. They concluded that CT measurements of maxillary sinus may be useful to support sex determination in forensic medicine (Teke *et al.*, 2007).

A study done by Uthman *et al.* in 2011 on maxillary sinus dimensions of 88 patients concluded that reconstructed CT image can provide valuable measurements for maxillary sinus and could be used for sexing when other methods are inconclusive. In this study, 4 measurements (width, length, height and total distances across both sinuses) were taken on each side and among these parameters, the left maxillary sinus height was the best discriminate variable between genders with accuracy rate of 71.6% (Uthman *et al.*, 2011).

In 2012, a study done by Amin and Hassan assessed 8 maxillary sinus measurements in 96 Egyptions which comprising of 48 males and 48 females aged between 20 to 70 years old. In this study, two variables showed significant difference i.e cephalo-caudal and size of the left maxillary sinus (accuracy rate of 70.8% for males). The study concluded that MDCT measurements of cephalo-caudal and size of left maxillary sinus were useful features in sex determination among Egyptions (Amin and Hassan, 2012).

A study done by Ekizoglu *et al.* (2014) showed that the size of the maxillary sinus was significantly smaller in female gender (P < 0.001). When discriminant analysis was performed, the accuracy rate was detected as 80% for women and 74.3% for men with an overall rate of 77.15%. They concluded that with the use of 1mm slice thickness CT, morphometric analysis of maxillary sinuses will be helpful for gender determination (Ekizoglu *et al.*, 2014).

Sharma *et al.* (2014) found that the dimensions and volume of the maxillary sinus of male was larger than those of female and this difference was statistically significant ($p < 0.05$) for sinus AP diameter and volume. Discriminant function analysis showed that 65.16% of males and 68.9% of females were sexed correctly. They concluded that CT measurements of maxillary sinus dimensions and volume may be useful for identification of gender in forensic anthropology to some extent when other methods are inconclusive (Sharma *et al.*, 2014).

Most of the previous studies on maxillary sinus dimensions have shown that the structure exhibited anatomic variability between genders and thus, was useful for sex identification. Introduction of MDCT with thin axial sections, sagittal and coronal reformatted images has allowed a more accurate assessment of this structure (Amin and Hassan, 2012). However, the measured variables or parameters were often specific to certain population and there were wide variability in degree of sexual dimorphism between the populations of different ethnic groups. Therefore, establishment of a standard data which is specific to a certain population is needed and more studies should be carried out to fulfil this.

3.0 OBJECTIVES

3.1 GENERAL OBJECTIVE

To determine the sex by measurement of maxillary sinus dimensions using MDCT in Malay adults.

3.2 SPECIFIC OBJECTIVES

1. To compare the mean difference of maxillary sinus dimensions between genders in Malay adults.

2. To determine the accuracy of maxillary sinus dimensions in identification of sex in Malay adults.

3.3 RESEARCH QUESTIONS

1. Does the measurement of maxillary sinus dimensions using MDCT are useful to differentiate between male and female in Malay adults?

2. What are the accuracy of measurement of maxillary sinus dimensions in determining the sex of Malay adults.