MORPHOMETRIC EVALUATION OF MAXILLARY SINUS AS A TOOL FOR GENDER DETERMINATION: 3D COMPUTED TOMOGRAPHY RECONSTRUCTION STUDY IN LUCKNOW POPULATION

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In the partial fulfillment of the requirement for the degree

Of

MASTER OF DENTAL SURGERY

In

ORAL MEDICINE AND RADIOLOGY

By

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Under the guidance of

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BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, BBU LUCKNOW (U.P)

BATCH: 2018-2021

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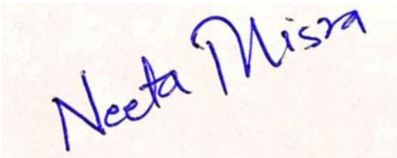

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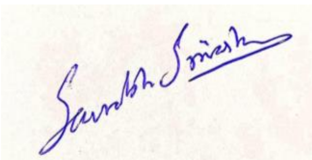

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"When you have too much to say you become speechless and when you have too much to write your pen fumbles"

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Dr. Sneha Agrawal

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ABBREVIATIONS

- BBDCODS - Babu Banarasi Das College of Dental Sciences
- BBDU - Babu Banarasi Das University
- OMR - Oral Medicine and Radiology
- F.O. - Forensic Odontology
- MS - Maxillary sinus
- MLD - Mediolateral dimension
- APD - Anteroposterior dimension
- SID - Superoinferior dimension
- CT - Computed Tomography
- 3DCT - 3-Dimensional Computed Tomography
- CBCT - Cone Beam Computed Tomography
- MPR - Multiplanar reconstruction
- PNS - Paranasal sinus
- DCI - Dental Council of India
- GBM - General Body Meeting
- IAFO - Indian Association of Forensic Odontology
- MRI - Magnetic Resonance Imaging
- CAT - Computed Axial Tomography
- HU - Hounsfield Unit
- SD - Standard Deviation
- CI - Confidence Interval
- +PV - Positive Predictive Value
- -PV - Negative Predictive Value
- AUC - Area Under the Curve
- DF - Discriminant function

ABSTRACT

INTRODUCTION

Personal identification is a subtle perception and often one of the most significant priorities in the investigation of criminal cases, mass disasters, and in forensic concerns. Gender determination in damaged and mutilated dead bodies or from skeletal remains constitutes the foremost step for identification in medico-legal examination. Various body parts are being used for gender determination such as skull, pelvis and paranasal sinuses in unknown remains. In explosions, warfare, and other mass disasters like aircraft crashes, the skull and other bones are badly disfigured, however it has been reported that maxillary sinuses remain intact due to their dense property.

AIM

The aim of this study is to assess the accuracy of morphometric evaluation of maxillary sinus using 3D CT Reconstruction as a diagnostic parameter for gender determination.

OBJECTIVES

1. To measure the maximum Supero-inferior dimension of right and left maxillary sinus in coronal multiplanar reformatted [MPR] image.

2. To measure the maximum medio-lateral dimension of right and left maxillary sinus in coronal MPR image.

3. To measure the maximum antero-posterior dimension of right and left maxillary sinus in axial MPR image.

4. To determine the volume of right and left maxillary sinus using "Region Growing" function of SYNGO CT VA48A software on Siemens 128 slice CT scan console from 3D image.

MATERIALS AND METHOD

This study was conducted in Department of Oral Medicine and Radiology of Babu Banarasi Das College of Dental Sciences, Lucknow (UP) in collaboration with Department of Trauma Surgery, KGMU, Lucknow. The study subjects consisted of 60 patients from both genders who were advised 3D CT Reconstruction of face in Department of Radiology, KGMU. Patients were selected on the basis of inclusion and exclusion criteria. The collected data was tabulated on spread sheets and subjected to statistical analysis.

RESULTS

Gender determination using Supero-inferior, medio-lateral, antero-posterior dimension and volume of the maxillary sinus on both sides showed statistically significant results with a higher percentage of sexual dimorphism in the case of volume.

CONCLUSION

Hence the study concludes that morphometric evaluation of maxillary sinus using 3D CT Reconstruction provides a fair degree of accuracy in gender determination which can be used as a helpful diagnostic parameter to predict the gender of a cranium of unknown origin.

KEYWORDS- Gender determination, maxillary sinus, 3D Computed Tomography

1. INTRODUCTION

The term Anthropology derives from the Greek terms (Anthropos) = human + (logos) = science, and it is the study of the human biological, cultural and linguistic conditions. Basically, anthropology is the study of humanity.[1] Forensic Anthropology is concerned with the anthropological methods and techniques to resolve the issues related to medico legal significance. It mainly focuses on the identification of human remains. Forensic science is the application of science to civil and criminal laws. Gender and age predictions are challenging and important procedures in the identification of unknown cranium. Gender determination is an important part of forensic odontology, and it is very necessary especially when natural calamities, mass disasters, and criminal cases occur where a forensic investigator receives unknown skeletal remains. [2,3,4]

George Buschan – A pioneer in dental anthropology has done numerous studies about anthropometric characteristics which is of fundamental importance.[5] Many parts of the skeleton can be used for identification of a person; however**,** the most reliable parts of the skeleton are those which are anatomically variable or which do not show any change due to trauma, illness or surgical intervention. Biological evidence are the evidences that are commonly recovered from crime scenes like bodily fluids, hair, tissue, bones, teeth, etc. [6] Personal identification is a subtle perception and often one of the most significant priorities in the investigation of criminal cases, mass disasters and calamities in forensic concerns. The study of anthropometric characteristics is of extreme importance to solve problems related to identification. Craniometrical characteristics are included among these characteristics, which are intricately connected to forensic dentistry. Radiographic methods are used in forensic for the identification of humans especially in cases where the body is decomposed, fragmented, or burned. [7]

Gender identification in damaged and mutilated dead bodies or from skeletal remains constitutes the foremost step for identification in medico-legal examination.[8] Various body parts are being used for gender prediction such as skull, pelvis, long bones, foramen magnum, Sella turcica, mandibular ramus, and paranasal sinuses in unknown remains. But in many instances these bones are recovered either in a fragmented or incomplete state where gender determination is extremely difficult to perform. So, it is key to use denser bones that are often recovered intact such as maxillary sinuses.[9]

Maxillary sinus is the first paranasal sinus to develop in the right and left maxillary bones and consists of two pyramidal shaped air-filled cavities lined with mucosa. The maxillary sinus appears at the end of the second embryonic month and complete by the age of 18 to 20 years after which reliable measurements can be achieved by radiographic images.[7] Sexual dimorphism refers to the systemic difference in the anatomy (either in shape or size) between individuals of different sexes in the same species. Researchers have revealed that the shape and size of the maxillary sinus differ between males and females and in various populations. [8]

Radiography was used as forensic tool for human identification, especially in cases where the body is decomposed, fragmented, or burned. Sinus radiography has been used for identification of remains and determination of sex and ancestry.[9]

Computed tomography (CT) scans are excellent imaging modality used to evaluate the paranasal sinuses, craniofacial bones, as well as the extent of pneumatization of the sinuses and provides detailed information that is not available from standard radiographs. Thus, CT scan is considered as gold standard to evaluate the true anatomy of sinuses.[11]

2. AIM AND OBJECTIVES

AIM

The aim of this study is to assess the accuracy of morphometric evaluation of maxillary sinus using 3D CT Reconstruction as a diagnostic parameter for gender determination in a representative population of Lucknow

OBJECTIVES

1. To measure the maximum Superoinferior dimension of right and left maxillary sinus in coronal multiplanar reformatted [MPR] image.

2. To measure the maximum mediolateral dimension of right and left maxillary sinus in coronal MPR image.

3. To measure the maximum anteroposterior dimension of right and left maxillary sinus in axial MPR image.

4. To determine the volume of right and left maxillary sinus using “Region Growing” function of SYNGO CT VA48A software on Siemens 128 slice CT scan console from 3D image.

5. To analyze above measurements to determine the accuracy in estimation of gender.

3. REVIEW OF LITERATURE

3.1 HISTORICAL BACKGROUND

3.1.1 THE EVOLUTION OF FORENSIC SCIENCE

The ancient world lacked standardized forensic practices, which helped criminals in escaping punishment. Criminal investigations and trials depended on forced confessions and witness testimony. However ancient sources contain several accounts of techniques that foreshadow the concepts of forensic science that was developed centuries later, such as the "Eureka" legend told of Archimedes (287–212BC).[12]

In the beginning of the seventeenth century, also known as the age of enlightenment, advancements in sciences and awakening of the social conscience resulted in revitalized interest in the field of forensic science. The forthcoming centuries witnessed the invention of modern forensic science techniques. In the 1814 Sir Mathieu Orfilla, known as Father of Forensic Toxicology, published the first scientific treatise on detection of poison. Later in the year 1835, Sir Henry Goddard became the first to connect a bullet to a murder weapon using physical analysis.[12]

3.1.2 HISTORICAL OVERVIEW OF FORENSIC DENTISTRY

Forensic odontology or forensic dentistry is the application of dental knowledge to those civil and criminal `laws that are enforced by police agencies in the criminal justice system.[13] Keiser-Neilson defined forensic dentistry as “that branch of forensic dentistry that in the interest of justice deals with the proper handling and examination of dental evidence and the proper evaluation and presentation of dental findings”.[14]

The first use of dental identification dates to 66 AD. Well-documented evidence to the use of teeth for identification began with Agrippina and Lollia Pauline case.[15] The first forensic identification in India started in 1193 where Jai Chand, Raja of Kanauji was murdered, and he was identified by his false teeth.[16]

In 1758 Peter Halket who was killed during French and Indian wars in a battle near Fort Duquesne was identified by his son by an artificial tooth.[17] Dr. Joseph Waren was killed in the year 1776, at the battle for Breed's Hill in Boston,. His face was not able to identify as he suffered from a brutal head wound. Paul Revere, a dental surgeon, identified Dr.Warren, dead body by a small denture that he had fabricated for him. [18,19]

First use of a dentist as an expert witness was well documented in 1814 in the case of Mrs. Janet Mc Alister in Scotland. Dr. James Alexander, Mrs. Alister's dentist, was the witness for the prosecution who identified the victim with the help of denture which perfectly fitted her oral cavity.[20]

A physician of Harvard university Dr. George Parkman in 18th century, in addition he was also an real estate speculator and money lender who failed to return from dinner on November 23rd 1849. John White Webster was suspected as it was known that he owed some amount of money from Dr. Parkman. When his laboratory was searched, remains of the human body were found. In court of justice, Dr. Parkman's dentist, Dr. Nathen Cooley Keep identified Dr. Parkman body, by his teeth as a part of upper and lower denture which he was made for Dr. Parkman 3 years earlier. Dr. Webster was found guilty and hanged over.[21]

3.1.3 FORENSIC DENTISTRY IN INDIA- THE CURRENT SCENARIO

Many Indian dentists, from both private clinical practice and university-based teaching and research roles, have significantly contributed to forensic odontology casework in India since the early 1970s.[22] In India interest in forensicdentistry has steadily risen over the past decade or so. The year 2000 was momentous for the specialty in India, when the Indian Association of Forensic Odontology (IAFO) was constituted by a small group of focused and enthusiastic dentists. The IAFO was subsequently registered in 2001 in Chennai, and annual national conferences have been organized since 2002.[23] Specialization in forensic odontology has been possible in several countries around the world, but while the Dental Council of India has included this as a subject in the B.D.S. Course Regulations (2007), a postgraduate course is yet to be started. It was first proposed at the DCI's GBM in Goa in December 2009, and in his inaugural address to the participants, the demand was endorsed by the then Govt. of Goa's Chief Secretary Shri Sanjay Kumar Srivastava.[22]

Many national and international societies have been registered and working in India and are actively participating for the promotion of this field such as the Indian Association of Forensic Odontology and Indo Pacific Academy of Forensic Odontology, which have been recently established with their headquarters in India. It is planning to bring out the scientific journal for the betterment of the field of forensic odontology. People from different faculties are getting involved in it to make forensic odontology a popular discipline. Forensic odontology thus has a lot to offer and is one of the most promising branches of dentistry that has a great scope of development in our country.[23]

3.1.4 SIGNIFICANCE OF FORENSIC DENTISTRY

Avon has classified forensic dentistry according to major fields of activity into civil, criminal, and research. Forensic dentistry specializes in numerous areas that include dental records as legal document, radiographic examination, age determination, anthropological examination, mass disaster identification, bite mark evidence, and family violence.[24]

Forensic dental identifications play a vital role in the identification of individuals when identification by visual or any other methods like finger printing fail. Dental identification of a person is based on unique individual characteristics of the dentition and dental restorations, relative resistance of the mineralized dental tissues and dental restorations to changes resulting from decomposition and harsh environmental extremes such as conditions of temperature and violent physical forces. [25] Forensic dentistry uses the skill of the dentist in personal identification during mass calamities, sexual assault, and child abuse to name a few. During all these disasters the bodies of most of the victims are mutilated beyond recognition by visual or any other methods. Under these situations forensic dental identification is extremely valuable. [26]

3.2 MAXILLARY SINUS

Paranasal sinus anatomy is variable from individual to individual and so is the incidence of the anatomical variations. Human skeletal remains can be used for identification of height, age, race, and sex that are considered the four fundamental elements of forensic science and physical anthropology. It has been reported that maxillary sinus stay intact in severely disfigured victims, whereas the other bones may be not.

The maxillary sinuses were 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 and first to develop of the paranasal sinuses. The alveolar process of the maxilla supports the dentition and forms the inferior boundary of the sinus.[27]

3.2.1 EMBROYOLOGY

MS begins to form during the 10th week of development. The mucosa at the deeper anterior end of the ethmoid infundibulum presents invaginations toward the surrounding mesenchyme. Fusion of these invaginations takes place, during the 11th week of development, giving rise to a single cavity representing the primordium of the MS. The primordial shape of the sinus is characterized as an oval cavity with smooth walls.[28]

According to **Borley NR, Standring S** rapid growth of the MS has been observed during two periods of development: from the 17th to the 20th week and from the 25th to the 28th week. This unique development describes the anatomical variation present in maxillary sinus. Ossification of the sinus begins during the 16th week of development, beginning in the lateral wall of the sinus and spreading to the anterior wall by the 20th week, and to the posterior wall by the 21st week. The medial wall shows signs of ossification by the 37th week of development. [29]

Lang J has stated that the floor of the sinus is related to the roots of the first premolar teeth at age 4 years and the second molar teeth at age five years and may extend to the third molar teeth and/or to the first premolar teeth, and sometimes to the canine teeth.[30]

After birth, the sinus continues to pneumatize into the developing alveolar ridge as the permanent teeth erupt. At 12-13 years, the sinus floor is in level with the nasal floor and at the age 20, with the completion of the eruption of the third molars, the pneumatization of the sinus ends and the sinus reaches 5 mm inferior to the nasal floor.[30]

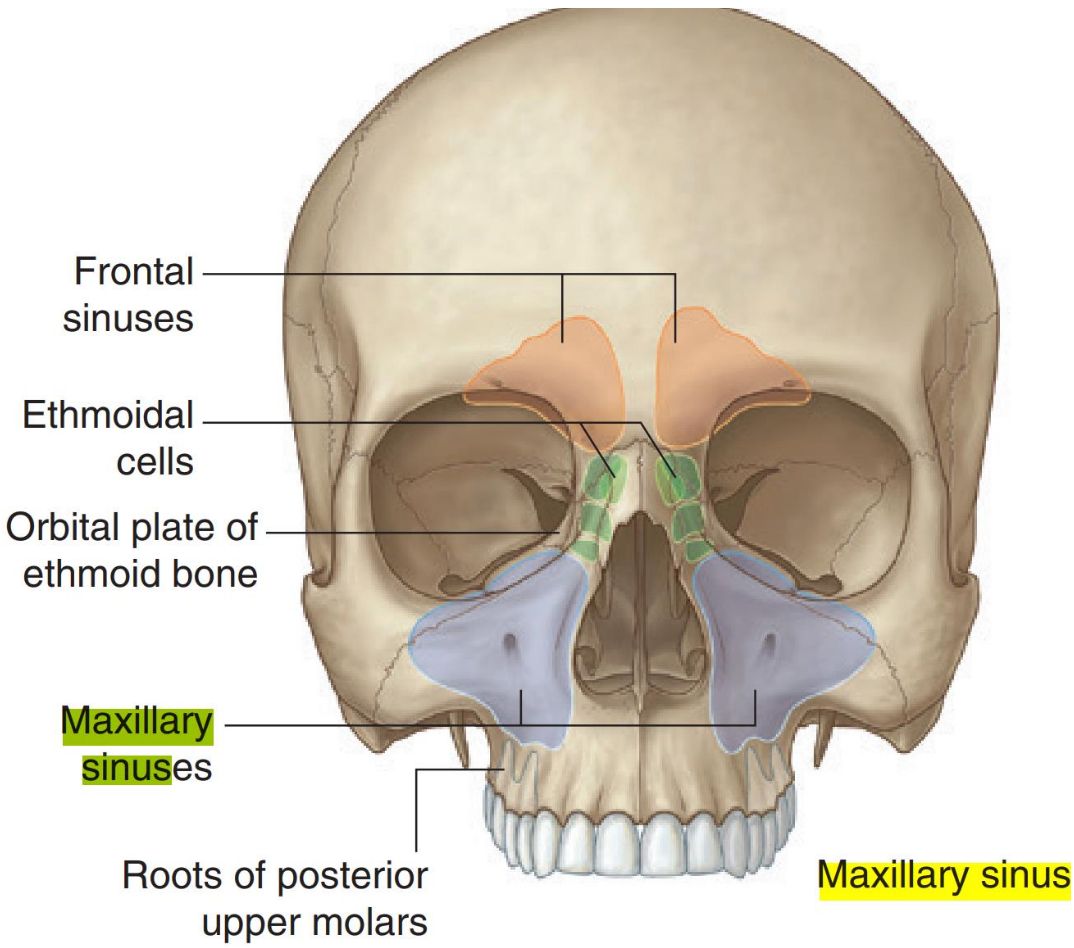
3.2.2 STRUCTURE

Richard L Drake, A Wayne, Adam W L Mitchell have stated the MS is pyramidal in shape and is the largest of the paranasal sinuses.[29] The anterior wall of the MS is formed by the facial surface of the maxilla and is internally grooved by the canalis sinuosus (which houses the anterior superior alveolar nerve and vessels).[29] The anterior wall has three major landmarks: (1) the thin canine fossa; (2) the infraorbital foramen located in the mid-superior region; and (3) the infraorbital groove. [29,31,32]The posterior wall is formed by the infratemporal surface of the maxilla.[29] It forms the anterior border of the pterygopalatine fossa.[31] The superior wall is formed by the triangular orbit floor, with the infraorbital groove running through it. [29,32] The roof of the sinus thickens toward the orbital margin, with a mean thickness of 0.4 mm medial to the infraorbital canal and 0.5 mm thick lateral to it.[30]

The medial wall of the MS separates the sinus from nasal cavity.[32] It is smooth on the sinus side and has the inferior nasal conchae on the nasal side. [29,32] The medial wall is rectangular in shape and is slightly deficient at maxillary hiatus. [29] This opening is partially closed in an articulated skull by part of the inferior turbinate, the uncinate process of the ethmoid bone, the perpendicular plate of the palatine bone, the lacrimal bone, and the overlying mucosa to form the ostium as well as anterior and posterior fontanelles. [29,31]

The ostium opens into the inferior part of the ethmoidal infundibulum, passing through the 7 hiatus, then finally into the middle nasal meatus. The ostium is elliptical in shape throughout prenatal development and located in the anterior third of the ethmoidal infundibulum. In adults, however, the ostium is situated between the middle and posterior thirds of the ethmoidal infundibulum and tends to be positioned closer to the roof of the sinus than the floor.[29] In some cases, the ostium is split into two sections via a mucosal membrane.[30] The lateral apex of the MS extends into the zygomatic process of the maxilla and can reach the zygomatic bone thus forming the zygomatic recess.[29]

The floor of the sinus is formed by the alveolar and palatine processes of the maxilla and lies below the nasal cavity [29,31], which is usually located from the mesial part of the first premolar to the distal part of the third molar with the lowest at the first and second molar. The floor of the sinus is separated from molar teeth by a thin layer of compact bone. [31] The maxillary posterior teeth root tips are in close relation to the floor of the sinus, with the root tips of the molar being closer to the sinus floor than the premolars. [33]



Photograph 1 : Anatomy of Maxillary Sinus

3.2.3 AGE CHANGES

At birth, the MS measures <7.0 mm in anteroposterior depth, <2.7 mm in width and <4.0 mm in height.[31] According to Lang J., the height of sinus development depends on various factors: pressure from the eyeball against the orbit wall, the traction on the inferior portion of the maxilla by the facial muscles, and the eruption of permanent detention. [30,32]

The MS grows most rapidly between 1 to 8 years of age, growing laterally past the infraorbital canal and inferiorly to the middle aspect of the inferior meatus. [31] At three years of age, the downward pull of the facial muscles continues to pull on the maxillary bones. [32] The roof of the sinus is at a more inferolateral position in childhood, before assuming its more horizontal position in adulthood due to progressing pneumatization. [31] The floor of the sinus lies somewhat lower than the insertion of the inferior nasal conchae at the end of the two years of age. [30] The floor lies at about the height of the inferior nasal conchae at seven years of age, and at the level of the floor of the nasal cavity at age 9 years. In some cases, the floor of the sinus can continue further into the hard palate in the medial direction, creating the palatine recess. [30]

Primary dentition does not have an influence on the growth of the MS because dental follicles of primary dentition are separated from the floor of the sinus via a thick layer of bone, ranging from 1.5 to 2.0 mm in thickness. [30] From ages 6 to 11 years, almost all tooth buds that are lateral to the incisors lie in immediate relation to the mucous membrane of the MS. [30] The MS reaches its adult size between 18 and 21 years of age with the eruption of the third molars. [34]

Researchers have revealed that the shape and size of the maxillary sinus differ among individuals, between males and females, and in various populations. Fernandes (2004) showed that ethnic and gender differences in maxillary sinus size, existed among the study populations.[35] They found that 48.6% of European maxillary sinuses had significantly larger antral volumes than Zulu maxillary sinuses, and men had larger maxillary sinus volumes than women.

Moreover, Butaric et al. reported that the mean values for the maxillary sinus ranged from 18.86 cm^3 for the Peruvian sample and 36.15 cm^3 for the Australian sample.[36] Another study reported that the mean maxillary sinus volume of girls was larger than that of boys at ages 4 and 9 years in a Japanese population and the maxillary sinus volume of boys tended to be larger than those of girls at ages 10 to 15 years. Moreover, the maxillary sinus volume in subjects aged 10 to 15 years tended to be larger than those of subjects aged 40 years and older.[37]

3.2.4 SIGNIFICANCE OF MAXILLARY SINUS

In unknown human remains, various body parts are used for gender prediction. These body parts include skull, pelvis, long bones, foramen magnum, sella turcica, mandibular ramus and paranasal sinuses. But in many instances these bones are recovered either in a fragmented or incomplete state where gender determination is extremely difficult to perform. In such cases, denser bones that are often recovered intact are of great significance in the process of gender determination.[11]

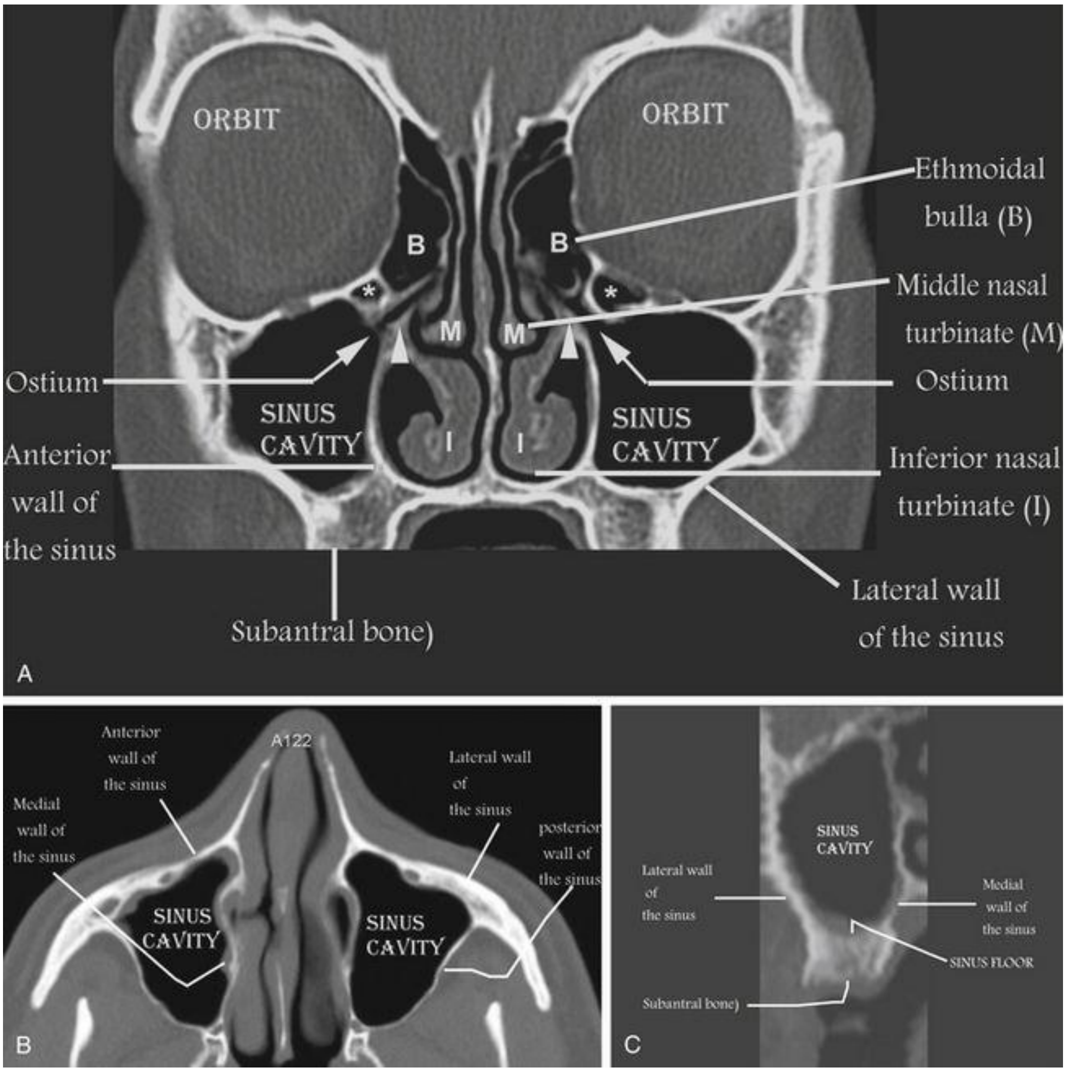
One such body part which is recovered intact in explosions, warfare, and other mass disasters such as aircraft crashes, when other bones are badly disfigured, is maxillary sinus. This uniqueness is attributed to the fact that maxillary sinus is dense enough to be recovered completely intact even in catastrophes like explosions, natural calamities etc. [11]

3.3 RADIOGRAPHY OF MAXILLARY SINUS IN FORENSICS

Many radiographic imaging modalities have been employed to study the maxillary sinus. The panoramic radiograph is the one such two-dimensional radiographic image technique used for a generalized evaluation of the orofacial complex. Although panoramic radiographs are useful for obtaining an overview of the orofacial complex, they have certain inherent limitations, such as unequal magnification, superimposition and geometric distortion etc across the image layer, leading to an inaccurate depiction of anatomy and pathology as well as unreliable measurement accuracy.[7]Therefore, panoramic radiographs are not a reliable method for morphometric measurements.

Another two-dimensional radiographic image technique used to evaluate maxillary sinus is lateral cephalometry. Khaitan T et al used this imaging modality to establish the reliability of maxillary sinus for gender determination. However, this radiographic view only provides a 2D representation of 3D object. [10]

Considering the complex structure of maxillary sinuses, MRI is another radiographic technique to depict the true anatomy of the maxillary sinus. It provides a more detailed anatomic picture for better evaluation of the sinuses in comparison to the 2-dimensional modalities.[2] Obtaining a three-dimensional view using computed tomography (CT) is a more accurate method of studying the maxillary sinus. For many years, CT has been preferred for the preoperative examination of the maxillary sinus, because it enhances the evaluation of its anatomy.[3]



Photograph 2 : Anatomy of maxillary sinus on CT scan

3.4 COMPUTED TOMOGRAPHY

Computed tomography (CT) is a technical and complex diagnostic imaging technique. Computed Tomography (CT) imaging is also called "CAT scanning" (Computed Axial Tomography). Tomography is derived from the Greek word ***"tomos"*** which means "slice" or "section" and ***"graphia"*** which stands for "describing". Computed tomography was first introduced 30 years ago and has since become an integral part of clinical practice.[38]

CT is based on developments in two fields - X-ray imaging and computing. X-rays were discovered in 1895 and within a few years become an established medical tool. In 1930s, tomography was being developed, enabling the visualization of sections through a body. By the 1960s, numerous researchers had worked independently on cross-sectional imaging, culminating in Hounsfield's work at EMI developing computed tomography (CT) for the EMI Scanner. The first CT scanning device was developed around 40 years ago. After a short time, a stack of CT sectional images was used to obtain 3D information. At the beginning of 1980s, clinicians used 3D imaging in craniofacial deformities. For craniofacial surgical needs, first simulation software was introduced in 1986. Then, the principles and applications of 3D CT imaging in medicine were published. A specific discipline was established on 3D imaging, dealing with different types of manipulation, and analysis of multi-dimensional medical structures.[39]

The first clinical CT scan on a patient was taken on 1st October 1971 at Atkinson Morley's Hospital, in London, England. It was scanned with a prototype scanner, developed by Godfrey Hounsfield and his team at EMI Central Research Laboratories in Hayes, west London. The scanner produced an image with an 80 x 80 matrix, taking about 5 minutes for each scan, with a similar time required to process the image data. Current CT scanners can produce images with a 1024 x 1024 matrix, acquiring data for a slice in less than 0.3 seconds, and are an integral part of a modern hospital's imaging resources.[40]

3.4.1 EVOLUTION OF COMPUTED TOMOGRAPHIC SCANNERS

In comparison to today's standards early computed tomographic scanners were extremely slow and required enormous computer facilities to generate comparatively crude scans. Advancements in tube technology and computer hardware and software have shortened scan times and improved the resolution of scans. The incorporation of slip ring technology into scanners in the late 1980s resulted in the development of spiral (helical) scanners. More recently, multislice scanners with scan times of less than a second have become widely available. These important technological improvements have been linked to newer and faster computers to provide the systems that are currently available.[41]

3.4.2 3-DIMENSIONAL COMPUTED TOMOGRAPHY

Three dimensional CT (3D CT) is basically a method of surface rendition of anatomy by means of a special computer software. This software is available in modern CT scanners as an optional package or may be available as an auxiliary unit to be used in tandem with an existing scanner.[42] This technique has been experimentally tried since the early 1980’s [43] and its use has been documented in the evaluation of craniofacial and peripheral musculoskeletal pathologies. [44]

3.4.3 BASIC PHYSICAL PRINCIPLES

3-D CT is a surface rendition. It is performed with the aid of a sophisticated software programme. The procedure involves obtaining plain axial scans of the region of interest. The computer is then provided with a selected ‘threshold’ attenuation value. The programme scans every CT slice line by line and records the exact co-ordinates of each pixel that shows an attenuation value higher than the chosen threshold. For example, if a attenuation value of +200 HU is chosen, only those pixels with an attenuation value of +200 HU or more will be included in the 3D image. These selected pixels represent voxels which contain tissue denser than the selected threshold.[45]

The scans are then stacked one on top of the other by the computer and adjacent selected pixels are joined to create a surface rendition. Then this image is assigned a surface shading by a virtual light source. Those pixels which are close to the light source are brightly illuminated while the distant ones are suitably shaded. Of course, those pixels which are perceived to be located behind another opaque pixel are not displayed on the surface image. This play of light and shadows creates the three-dimensional effect. [40]

Since the selection of a pixel for incorporation into the 3D image is an all or none phenomenon, there is no grey scale differentiation perceived between the pixels chosen; they are all uniformly white. This means that individual tissue differences cannot be highlighted by this technique. [46] Hence the application of 3D CT is mostly limited to the imaging of bony pathologies. Development of 3D reconstructions aims to improve the way of presentation by simulation of real specimens.

3.5 GENDER DETERMINATION

Establishing identification is necessary for unknown deceased person in homicide, suicide, accident, mass disasters, and for culprits hiding their identity.[47] This identification on skeletal and decomposing human remains is one of the most difficult skills in forensic science. Determination of gender from remains of human skeleton is an important forensic procedure.

In adult skeleton, gender determination is the first step followed by age and stature, as both are dependent on gender. It has been reported that gender can be determined with an accuracy of 100 % if entire skeleton is available. A total of 98% accuracy can be achieved from both the pelvis and skull.[6] In case where the entire skull is not available, maxilla may play an important role in gender determination.

Sahlstrand-Johnson, P., Jannert, M., Strombeck, A. et al. **(2011)** conducted a study and determined dimensions of 120 maxillary and frontal sinuses from head CTs independently by two radiologists. The results showed that the mean value, SD, and median value of the volume of the maxillary sinuses of both sides were 15.7, 5.3, and 15.2 cm^3, respectively. They found the mean value of the maxillary sinus volume to be significantly larger in males than in females ($P = 0.004$). There was no statistically significant correlation between the volume of maxillary sinuses with age or side. The automatically estimated volume of the maxillary sinuses was 14-17% higher than the calculated volume. There was high inter-observer agreement regarding the different measurements performed in this study. Different types of incidental findings of the paranasal sinuses were found in 35% of the patients. Furthermore, they showed a good correlation between the manually and the automatically estimated maxillary sinuses volumes.[48]

Uthman AT, Al-Rawi NH, Al-Naaimi AS, Al-Timimi JF (2011) took measurements of maxillary sinuses on CT to determine its usefulness in gender identification. The study was undertaken to find the accuracy and reliability of maxillary sinus dimensions measurement in gender classification using reconstructed helical CT images. Eighty-eight patients (43 men and 45 women), in the age range of 20 to 49 years were selected in this study. The width, length, and height of the maxillary sinuses along with the total distance across both sinuses were measured. Data was subjected to discriminant analysis for gender using multiple regression analysis. Maxillary sinus height was found to be the best discriminant parameter that could be used to study sexual dimorphism with an overall accuracy of 71.6%. Using multivariate analysis, 74.4% of male sinuses and 73.3% of female sinuses were sexed correctly. The overall percentage for sexing maxillary sinuses correctly was 73.9%.[49]

Vidya C.S., N.M. Shamasundar, Manjunatha B., Keshav Raichurkar (2012) conducted a study,in Mysore, on 30 dry skulls and obtained the skulls of known sex from recently buried bodies. Macerated skulls were taken, cleaned thoroughly, and subjected for 3D axial multislider, Siemen's sensation cardiac 16 slice CT scan at Vikram hospital Mysore. They obtained the images with slice collimation of 1mm thickness. Axial and coronal images with slice thickness of 4mm were obtained for measurements of height, AP length and width of maxillary sinuses of both sides by using dedicated software. Volume of maxillary air sinuses of both sides were automatically estimated using syngo volume Siemens, by area length method using freehand interactive drawing of area in each axial sections. Statistical Analysis Statistical analysis was performed with Systat 13 package. Mean and SD to assess the level of the parameters in males and females were determined. Differences with a p value, $p < 0.05$ were considered significant. The volume of the maxillary sinuses of both sides was significantly greater in males compared to female skulls. The p value of left width and right sided volume of maxillary sinuses 0.015 and 0.021 respectively were considered statistically significant.[50]

Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. **(2013)** used CT images to measure the mediolateral, superoinferior, and anteroposterior dimensions and the volume of the maxillary sinuses in 30 patients (15 males and 15 females) to investigate whether these parameters could be used to determine the gender of an individual for forensic identification. The mean, along with the standard deviation was calculated for all the dimensions of the right and the left maxillary sinuses, namely ML, SI, and AP, for both genders. For the right maxillary sinus, the mean value of the ML dimension was found to be 27.53 ± 4.26 mm in males and 25.12 ± 6.75 mm in females. The mean of SI dimension was 38.21 ± 5.77 mm in males and 33.34 ± 6.57 mm in females. Also, the mean of AP dimension was 42.60 ± 3.79 mm in males and 36.00 ± 4.09 mm in females. For the left maxillary sinus, the mean value of the ML dimension was found to be 27.01 ± 5.04 mm in males and 23.22 ± 6.21 mm in females. The mean value of the SI dimension was 36.99 ± 4.45 mm in males and 33.11 ± 6.71 mm in females. Also, the mean value of AP was 40.80 ± 2.73 mm in males and 37.20 ± 2.96 mm in females. The t-test for independent samples was used to compare these values in both genders and the data were subjected to discriminative analysis using SPSS software. A statistically significant ($P < 0.05$) difference was found in the right SI dimension, left SI dimension, and the AP dimension of the left maxillary sinuses between males and females. A significant ($P < 0.01$) difference was found in the right AP dimension of the maxillary sinus between males and females. The other maxillary sinus dimensions showed a pattern of being larger in males than in females; however, the difference was not statistically significant. A comparison was done between the dimensions of the right and left maxillary sinus within males and females separately. On non-statistical comparison in males, the right maxillary sinus gave an impression of being slightly larger than the left maxillary sinus in its overall dimensions. Similarly, in females, the right maxillary sinus was marginally larger in dimensions than the left maxillary sinus, except for the AP dimension. Aberrantly, the AP dimension of right maxillary sinus was observed to be less than that of the left maxillary sinus in females. However, these intra-gender findings were statistically insignificant ($P > 0.05$). Their method was able to predict the gender with an accuracy of 80.0% in males and 86.7% in females, with an overall accuracy rate of 83.3%. [3]

Tambawala SS, Karjodkar FR, Sansare K, Prakash N. (2013) conducted a retrospective study in 2013 to evaluate the sexual dimorphism of maxillary sinus dimensions using the CBCT imaging modality. They retrieved one hundred and thirty-two CBCT scans of bilateral maxillary sinuses retrospectively from the database of the Oral Radiology unit. Out of these 132 scans they selected thirty CBCT scans with 15 male and 15 female subjects and age ranging from 20 to 70 years. They included only high-quality reconstructed images of bilateral maxillary sinuses and all low-quality images with blurring or artifacts caused by metallic objects were excluded. They measured the height, width, and depth of the sinuses. The collected data was then subjected to descriptive and discriminative functional analysis with generation of multiple logistic regression model and ROC analysis. The result showed that the overall values of the parameters were significantly greater in the males as compared to the females with the right height (90.0%) and the left height (83.3%) being the best predictor. Their study proposed the importance of sexual dimorphism of maxillary sinus dimensions particularly the sinus height, when other methods used in the field of forensics seem to be indecisive.[51]

Lakshmi N. Kiruba, Chandni Gupta, Sandeep Kumar, Antony S. D'Souza (2014) conducted a radiographic study to estimate different dimensions of the maxillary sinuses measured on head CT, and their relations to the gender of the individuals. They included 200 (M = 120, F = 80) normal cranial computerized tomographic images (CT) of subjects between the age groups of 18 and 80 years. The width, height, and depth measurements were made where the maxillary sinus was in its widest position with the help of the measurement equipment on Philips Brilliance 64 CT scan, as the measurement technique. Width was measured in axial section and height, depth in sagittal section. The statistical analysis for gender and age comparison for all parameters was done using t-test for independent samples to compare these values in two groups. Discriminative analysis was performed to detect gender by using data obtained from CT scans. The analyses were performed by using the SPSS 14 package program. On statistical analysis they found the mean width, height, and depth of maxillary sinus in male on both right and left side were 27.8, 28.2, 39.9, 39.6, and 40.0, 39.7 mm but in females were 26.6, 26.7, 36.8, 37.1, and 36.6, 37.4 mm. The discriminative analysis showed that the accuracy of maxillary sinus measurements i.e., the ability of the maxillary sinus size to identify gender was 55% in females and 69.5% in males.[52]

Ruhi Sidhu, Sunira Chandra, Parvathi Devi, Neeraj Taneja, Kunal Sah, Navdeep Kaur (2014) took lateral cephalograms of 50 subjects (25 males and 25 females) and analyzed morphometric parameters of maxillary sinus using AutoCAD 2010 software (Autodesk, Inc.). The mean area and perimeter of maxillary sinus in males was 1.7261 cm^2 and 5.2885 cm whereas, the mean area and perimeter in females was 1.3424 cm^2 and 4.3901 cm. In-group centroids if someone's discriminant function (DF) score is close to 0.838 then the subject are supposed to be male. Whereas those having DF score closer to −0.838 are supposed to be females. DF analysis showed that, 76% of the original grouped cases were correctly classified. Hence, the overall sensitivity and specificity was found to be 80% and 72% respectively.[7]

Ekizoglu O, Inci E, Hocaoglu E, Sayin I, Kayhan FT, Can IO (2014) conducted a computed tomographic study to morphometrically evaluate maxillary sinuses to determine gender. For morphometric analysis, coronal and axial paranasal sinus computed tomography (CT) scan with 1-mm slice thickness was used. A total of 140 subjects (70 women and 70 men) were enrolled (age ranged between 18 and 63). The size of each subject's maxillary sinuses was measured in anteroposterior, transverse, cephalocaudal direction. Along with these dimensions volume was also measured. In each measurement, the size of the maxillary sinus was found to be significantly smaller in female gender ($P < 0.001$). When discrimination analysis was performed, the accuracy rate was detected as 80% for women and 74.3% for men with an overall rate of 77.15% [53]

Kanthem RK, Guttikonda VR, Yeluri S, Kumari G (2015) conducted a study in Andhra Pradesh, to evaluate dimensions of right and left maxillary sinuses of a total of 30 patients including 17 male and 13 female, from plain CT using SYNGO software and statistical analysis. They measured the height, length, width, and calculated the volume of the maxillary sinus on both sides by using the formula- Volume = (height × depth × width × 0.5). After measuring all dimensions, they performed statistical analysis by Mann-Whitney U-test. Sexual dimorphism was calculated using the following formula: Percentage of dimorphism = $\{(X_m/X_f) - 1\} \times 100$ where X_m stands for mean male maxillary sinus dimension and X_f stands for mean female maxillary sinus. dimension. The mean values of the right-side maxillary sinus height, length, width, and volume for males is 4, 3.76, 2.63, and 39.93, respectively, and in case of females it was 3.09, 3.12, 2.23, and 21.53. According to these dimensions statistically significant results were found with P = 0.00001, 0.00001, 0.00701, and 0.00001, respectively. The sexual dimorphism of maxillary sinus right side height, length, width, and volume showed the percentages of 29.44%, 20.51%, 17.937, and 85.46%, respectively.The mean values of left side maxillary sinus height, length, width, and volume for males is 3.93, 3.73, 2.53, and 37.64, respectively, and in case of females it was 3.07, 3.12, 2.20, and 21.10. The maxillary sinus on the left side also showed statistically significant results with P = 0.00001, 0.00001, 0.0110, and 0.00001, respectively. The sexual dimorphism of maxillary sinus of left side height, length, width, and volume showed the percentages of 28.01%, 19.5512%, 15, and 78.38%, respectively. They found that the dimensions and volume of maxillary sinuses of right and left side were notably larger in males compared with females. They showed statistically significant values with a higher percentage of sexual dimorphism in the case of volume with 85.46% for the right side and 78.38% for the left side.[11]

A Abdul-Hameed, AD Zagga, SM Ma'aji, A Bello, SS Bello, JD Usman, MA Musa, AA Tadros (2016) to determine the size of the maxillary antrum and compare the depth, width, and height of the maxillary sinus between genders and to establish a baseline for values using CT. They obtained head CT scans of one hundred and thirty subjects (79 males, 51 females), between 20 and 80 years, with normal maxillary sinus CT anatomy. They took the measurements between the widest points of the sinuses, anteroposterior (AP) and transverse diameters from axial images, craniocaudal diameter from coronal and sagittal images, and volumes were determined by the product of these three-dimensional and slice thickness. Their results showed that in males, the mean craniocaudal, transverse, AP diameters and volume on the right were: 32.21 ± 5.56 mm, 24.18 ± 5.80 mm, 36.94 ± 4.73 mm, and 14.98 ± 6.53 cm^3. On the left, it was 32.38 ± 5.33 mm, 24.12 ± 5.81 mm, 36.84 ± 5.31 mm, and 15.08 ± 6.66 cm^3 respectively. Similarly in females, values on the right were: 30.93 ± 6.09 mm, 23.14 ± 4.70 mm, 36.29 ± 4.71 mm and 13.26 ± 5.04 cm^3, and left was, 31.14 ± 6.00 mm, 23.69 ± 5.50 mm, 36.43 ± 4.64 mm, and 16.06 ± 17.96 cm^3 respectively. Indicating that statistically insignificant difference existed in the right maxillary sinus volume between males and females.[54]

Bhusal D, Samanta P, Gupta V, Kharb P (2017) to find out the volume and maximum Anteroposterior (AP) diameter of the maxillary air sinus and the anatomical variations related to it. CT images of 100 healthy subjects were subjected to the measurements of volume and maximum AP diameter of right and left maxillary air sinus using Auto contour software. Student's 't'-test was applied to find out significant difference between males and females. They observed that the volume of right and left maxillary sinuses in males were found to be 12.95±4.48 cm^3 , 13.26±3.94 cm^3 , and in females 10.59±3.37 cm^3 , 10.16±2.92 cm^3 respectively. A statistically significant difference was recorded between volume of right and left maxillary sinuses in males and females. Maximum AP diameters of right and left maxillary sinuses in males were 37.31±4.62 mm, 37.74±3.59 mm and in females were 36.15±3.92 mm, 35.57±3.50 mm respectively. Statistically significant difference was observed between the maximum AP diameter of males and females for left maxillary sinus.[55]

Srisha V, Jayalakshmi (2017) assessed the accuracy of maxillary morphometric parameters in gender determination. They retrospectively acquired 500 maxillary sinus CBCT images from the database. The CBCT scans obtained were screened according to the inclusion and exclusion criteria. Finally, 200 CBCT scans of bilateral maxillary sinuses (right and left) with 100 males and 100 females subjects with age ranging between 20 to 70 years were selected and evaluated for the following parameters: width, length, height, area, perimeter, and volume. e. They included Only high-quality reconstructed images of bilateral maxillary sinuses. Blurred or artifacts caused by metallic objects with low-quality images scans with pathologically destructed maxillary sinus from trauma, tumors or other diseases and history of previous surgeries were excluded from the study. All measurements were carried out using CS softwareVer.3.3.11. All the values were recorded on an excel sheet and were subjected to statistical analysis. The mean and standard deviation of both right and left maxillary sinuses measurements were calculated and compared by using unpaired t-test with a p-value less than 0.05 taken as a significant level. On comparison of the measurements of maxillary sinus between males and females they found that the overall parameters were significantly greater in males than in females. The result of the discriminative analysis showed that the ability of maxillary sinus to identify gender was 69% in males, 68% in females with an overall accuracy of 68.5%. [56]

Bangi B. B., Ginjupally U, Nadendla L K, Vadla B (2017) did a radiographic study where CT images were used to measure the mediolateral, superoinferior, and anteroposterior dimensions and the volume of the maxillary sinuses in 100 patients (50 males and 50 females) to determine the gender of an individual for forensic identification. The volume of the maxillary sinus was calculated by using the formula: Volume = (height x depth x width) x 0.5. For the right-side maxillary sinus, the mean value of ML, SI, and AP for males is 3.30 ± 3.21 cm, 3.16 ± 0.51 cm, and 3.57 ± 0.41 cm, respectively, and in case of females it was 2.48 ± 0.44, 2.92 ± 0.53, and 3.37 ± 0.41, respectively. For the left side maxillary sinus, the mean value of ML, SI, and AP for males is 2.61 ± 0.54, 3.17 ± 0.5, and 3.55 ± 0.38, respectively, and in case of females it was 2.44 ± 0.42, 2.93 ± 0.54, and 3.38 ± 0.38, respectively, which showed statistically significant larger dimensions in males when compared to females. Discriminative analysis was done using the values derived and the T-test for independent samples was used to compare these values in male and female. The accuracy of gender prediction was found to be 72% in both males and females from measurements of right maxillary sinus. The accuracy of gender prediction was found to be 72% in males and 76% in females from measurements of left maxillary sinus. The accuracy of gender prediction was found to be 84% in males and 92% in females by combining right and left maxillary sinus dimensions.[57]

Etemadi S, Seylavi G, Yadegari A. (2017) conducted a radiographic study to measure the maxillary sinus volume using cone beam computed tomography (CBCT) and assess its correlation with gender and some craniofacial indices. It was a cross-sectional study, in which they took CBCT scans of 70 patients (35 males and 35 females) who were older than 18 years of age. They used axial CBCT sections with 2mm slice thickness to measure the maxillary sinus volume.

Digimizer software was utilized for volume measurement. Sinus volume was calculated using the formula as volume = sum of the thickness of each slice multiplied by the surface area of each slice. They measured the width and height of the palate in the coronal plane, anterior-posterior length of the palate in the sagittal plane and distance between the two zygomatic buttresses on the axial CBCT sections in both males and females. For statistical analyses they used Pearson's correlation coefficient, independent t-test, and paired t-test. The results showed that the mean maxillary sinus volume was 15.9±6.05 cm^3 and 13±2.85 cm^3 in males and females, respectively. The mean volume of the maxillary sinus was larger in males, and they noted a significant correlation between the mean volume of the maxillary sinus and width and height of the palate as well as the distance between the two zygomatic buttresses ($P<0.05$). They found that despite the larger volume of the maxillary sinus in males, this parameter cannot be used for sexual identification because the area under the receiver operating curve (ROC) was 62.7%.[58]

Urooge A ,Patil BA (2017) conducted a study in Oxford Dental College and Research Centre, Bengaluru, to evaluate the size and volume of Maxillary Sinus (MS) in determining gender by CBCT. They acquired Bilateral maxillary sinus images (left and right) for 100 patients (50 females and 50 males) and different parameters (width, length, height, area, perimeter, and volume) were measured and evaluated. Mean and standard deviation of both maxillary sinuses' measurements were calculated and compared. The data was subjected to discriminative statistical analysis and analyzed by applying unpaired t-test. Comparison between male and female groups showed statistically insignificant differences on both the right and left sides in relation to the maxillary sinus length, height, area, volume, and perimeter. However, the female group showed statistically significant higher values for left side MS width (p=0.041) and left side MS width can be used to determine gender with an overall accuracy of 60%. The result of discriminative analysis shows that the ability of the maxillary sinus to identify gender was 68% in males and 74% in females with an overall accuracy of 71%.[59]

Luz, J., Greutmann, D., Wiedemeier, D. et al. (2018) conducted a radiographic study at the Department of Cranio-Maxillofacial and Oral Surgery at the University of Zurichused.They utilised cone-beam computed tomography to measure the 3D osseous and soft tissue defined volume and surface area of the maxillary sinus. They further evaluated the possible associations with patient-specific and sinus-related variables. They analyzed a total of 128 maxillary sinuses in 64 patients using cone-beam computed tomography data. They calculated the surface area and volume of the osseus maxillary sinuses as well as of the remaining pneumatized cavities in cases of obliterated sinuses by the implant planning software SMOP (Swissmeda AG, Baar, Switzerland). They also recorded patient-specific general variables such as age, gender, and dentition state as well as sinus-related factors including apical lesions, sinus pathologies, and number of teeth and roots communicating with the maxillary sinus. The results showed that mean surface area was 39.7 cm^2 and mean volume 17.1 cm^3 for osseus bordered sinuses. For the remaining pneumatized cavities, mean surface area was calculated as 36.4 cm^2 and mean volume 15 cm^3. The calculated mean volume of obliterated sinuses (42.2% of all sinuses were obliterated) was 5.1 cm^3. Further, they found an association between the obliterated volume and the presence of pathologies. Male patients showed a significantly higher mean osseus volume compared to female patients in this study.[60]

Dangore-Khasbage S, Bhowate R. (2018) conducted a study at the Datta Meghe Institute of Medical Sciences, Wardha, India, to assess the utility of the morphometry of the maxillary sinuses using computed tomography (CT) for gender determination. They analyzed CT scans of 200 patients (100 males, 100 females). The measurement of the mediolateral (ML), superoinferior (SI) and anteroposterior (AP) dimensions, as well as of the volume and the antero-lateral (AL) angle of both the maxillary sinuses, was performed using a CT scan. Head circumference and head area were also measured on an axial image to evaluate the correlation between the sinus volume and the head circumference and head area. The data was then statistically analyzed. The mean of the mediolateral, superoinferior and anteroposterior dimensions, volume and AL angle of the right and left maxillary sinuses showed a statistically significant difference between males and females. Head circumference as well as head area were observed to be greater in males than in females, with a statistically significant difference. A positive correlation was observed between the volume of maxillary sinuses and the head circumference and head area on both sides and in both genders; however, it was not significant. Amongst all the parameters, the left AL angle with a 78.5% accuracy was found to be the best discriminative parameter, followed by the right AL angle with a 73% accuracy. The overall accuracy of the maxillary sinus parameters to identify gender was 86%.[61]

Sheikh NN, Ashwinirani SR, Suragimath G, Shiva Kumar KM (2018) conducted a study at Krishna Institute of Medical Sciences, Karad, to analyze gender-based differences in frontal and maxillary sinuses using paranasal sinus view radiographs in Maharashtra population. They included a total of 100 patients (50 males and 50 females) in their study. Paranasal sinus (PNS) views were taken using MARS 50 machine using exposure parameters of 60–70 kVp, 35–40 mA. Height and width of maxillary and frontal sinuses were measured, and comparison was made between genders and between the sides. They observed that the side-wise comparison of maxillary sinus height showed higher values on left than right in both males and females, whereas when width was compared, right width was higher than left width in both males and females. They found that side-wise comparison of frontal sinus parameters both width and height showed higher values on the left side than the right side in both males and females, but the values of both the sinuses were not statistically significant. They found that the width of left maxillary sinus and frontal sinus could be used as discriminate parameter to study sexual dimorphism with an accuracy of 59% and 58% respectively.[62]

Farias Gomes A, de Oliveira Gamba T, Yamasaki MC, Groppo FC, Haiter Neto F, Possobon RF (2018) conducted a formula-based study in 2018 in Brazilian Population. They took linear and volumetric measurements of the maxillary sinus bilaterally in 94 CBCT scans from 45 males (mean age 25.2 ± 0.79) and 49 females (mean age 23.7 ± 0.50). The OnDemand 3D software was employed for linear measurements (height, length and width, and the largest distance between the right and left maxillary sinuses), while the ITK-SNAP 3.0 segmentation software was used to acquire the volume. The data obtained was applied to a mathematical model for sex estimation. To validate the developed formula, they selected another sample composed of 60 CBCT images of Brazilian individuals. They observed that overall, maxillary sinuses' measurements were significantly higher in males, without statistically significant differences between the right and left sides within each group. The most dimorphic measurement was the height, with an accuracy of 77.7% regarding sex estimation. The formula created lead to a sex estimation of 87.8% for females and 80% for males, with an overall accuracy of 84%. When the formula validity was tested in another sample, it showed an accuracy of 82.4%. The formula developed through measurements in the maxillary sinus using CBCT scans showed an accuracy of 84% for sex estimation and could be applied as a complementary method for human identification in the Brazilian population.[63]

Usha R.S., Venkateswara R G, Rakesh K D, Taneeru S, Yeluri S, Praveen K M (2018) conducted a radiographic study in Department of Radiology, Mamata General Hospital, Khammam. In their study 60 subjects (30 males and 30 females) ranged from 21 to 73 years of age were included. They used MRI in which maxillary sinus dimensions (height, width, and depth) were measured using Siemen’s software, and statistical analysis was done. The width and depth were measured on the axial views while the height was measured on coronal view of MRI. All the three dimensions of the maxillary sinus were measured by single observer and the volume of each maxillary sinus was also calculated using the following equation: Volume = (height × depth × width × 0.5). The mean values of the right-side maxillary sinus height, width, depth, and volume in males were 3.89, 4.11, 4.32, and 34.62, respectively, whereas in case of females it was 3.21, 3.79, 3.88, and 23.65, respectively. There was a statistically significant difference between the mean dimension of height, width, depth, and volume of the right maxillary sinus with P values of 0.00001, 0.00001, 0.00001, and 0.00001, respectively. The mean values of the left side maxillary sinus height, width, depth, and volume for males were found to be 3.88, 4.09, 4.27, and 33.91, respectively while in case of females it was 3.18, 3.74, 3.82, and 22.70, respectively. There was a statistically significant difference between the mean dimension of height, width, depth, and volume of the left maxillary sinus with *P* values of 0.00001, 0.00001, 0.00001, and 0.00001, respectively. The volume and dimensions of the maxillary sinus were more in males when compared to the females with a statistically significant difference. The highest percentage of gender dimorphism was seen in the volume of left maxillary sinus. [64]

Subasree , Dharman S (2019) conducted a lateral cephalometric study to measure the dimensions of maxillary sinus and to determine its relationship with age and gender which will be an aid in forensics. A total of 90 lateral cephalometric images were taken consisting of 45 males and 45 females aged between 10 and 40 years with individual's chronological age. The study parameters – maxillary sinus height, width and index were measured. The mean values and standard deviation were obtained using paired t test. Discriminant equation was obtained for both the genders. Accuracy of the equation was tested. Mean values of all the parameters were compared with age with the help of Tamhane post hoc tests. They found that the maxillary sinus height was higher in males than females with a statistically significant p value of < 0.049, indicating it to be comparatively a better indicator for sex determination among all the variables. Hey also calculated that gender could be predicted using the discriminant functional analysis, with the overall accuracy rate of 65.7%. Maxillary sinus height and width showed good correlation with age between 11- 20 years when compared with 21-30 years and 31-40 years age groups but weak correlation between 21-30 years to 31-40 years age groups, whereas maxillary sinus index showed weak correlation with age among all age groups on Tamhane post hoc analysis.[65]

Abasi P, Ghodousi A, Ghafari R, Abbasi S (2019) conducted a descriptive-analytic study, in which 80 lateral cephalograms were obtained from 20 to 40-year-old individuals (40 males and 40 female). They performed height and anterior-posterior length of the maxillary sinus was using CATIA V5R20 (a software package for image analysis). Maxillary sinus area was calculated using discriminant analysis in AutoCAD. The mean maxillary sinus height was 40.48 mm in males and 38.7 mm in females. The mean maxillary sinus length was 40.31 mm in males and 37.31 mm in females. The area of the maxillary sinus was 1201.2 mm^2 in males and 1043.4 mm^2 in females. They developed two discriminant analysis models, (one based on the height and length of the maxillary sinus and the other based on sinus area) for sex estimation. The mean height, length and area of the maxillary sinus were significantly larger in males than in females ($P < 0.05$). The length/width perform better than area for sex estimation but, it is greatly overshadowed by the fact that both measures perform barely better than chance. They found the classification accuracy to be less than 80%, they did not find their method to be reliable and therefore not recommended for sex estimation.[66]

Alhazmi A et al(2019) conducted a 2-D and 3-D Volumetric Cone-beam Computed Tomographic Cross-sectional Study to investigate the correlation of the 2-D and 3-D maxillary sinus dimensions with the linear measurement of the maxillary arch width (MAW) in adult individuals. They obtained 54 cone-beam computed tomography scans and measured Maximal vertical diameter (maximal height) of the maxillary sinus (MSH), maximal horizontal diameter (maximal width) of the maxillary sinus (MSW), maximal anteroposterior diameter (maximal length) of the maxillary sinus (MSL), MAW, and maxillary sinus volume (MSV) using 3-D Slicer software. The Spearman's rank correlation coefficient (rho-ρ) was applied to analyze the strength and type of the relationship between variables. They found moderate to strong correlation (ρ range between 0.65 and 0.80) between MSV for all linear measurements of the maxillary sinuses on both sides in both genders. In contrast they observed that maxillary sinus length showed the weakest correlation with MAW. They concluded that the relationship of MAW with MSV on both sides shows a stronger correlation than its relationship with all 2-D linear measurements of maxillary sinuses.[67]

M Gulec , M Tassoker , G Magat , B Lale , S Ozcan , K Orhan (2019) conducted a radiographic study with the aim to determine the volumetric size of the maxillary sinus and investigate the effect of gender and age on maxillary sinus volume (MSV). They used cone-beam computed tomography (CBCT) images in a Turkish subpopulation. It was a retrospective volumetric CBCT study which was carried out on 133 individuals (84 females, 49 males) between 8 and 51 years old. They measured MSV using the MIMICS 21.0 software (Materialise HQ Technologielaan, Leuven, Belgium). SPSS 21.0 (SPSS, Chicago, IL, USA) software was used for statistical analysis. They recorded the mean and standard deviation of both maxillary sinuses to compare to gender and age. P values < 0.05 were considered to indicate statistical significance. They inferred that the mean volume of the right maxillary sinus was 13.173 cm3, while for the left was 13.194 cm3. There was no significant difference between right and left maxillary sinus volumes (p > 0.05). There was no significant correlation between MSV and age (p > 0.05). They found that MSV did not change according to gender (p > 0.05). [68]

Nadia Araneda , Marcelo Parra , Wilfredo A González-Arriagada , Mariano Del Sol , Ziyad S Haidar , Sergio Olate (2019) presented a strategy for morphological analysis of the MS using three-dimensional (3D) printing acquired through cone-beam computed tomography images. They conducted a cross-sectional exploratory, single-blind study was conducted, including 24 subjects in which MSs were reconstructed, and 3D virtual modeling was done bilaterally, obtaining 48 physical models generated on a 3D printer. They performed the statistical analysis using tests of normality and tests using a value of $P < 0.05$ to establish statistical significance. They observed the mean of the MS volume to be 15.38 cm^3 (±6.83 cm^3). The minimum volume recorded by them was 5.4 cm^3 and the maximum was 30.8 cm^3. In a bilateral comparison of the right and left volume of the same individual, they observed no significant differences ($P = 0.353$). The most prevalent shape in their study was pyramidal with a square base with a prevalence of 66.7%. Related to gender, significant differences were observed only for the left volume ($P = 0.009$), with the mean volume being significantly greater in the men (19.69 cm^3) than in the women (12.28 cm^3).[69]

Kandel S, Shrestha R, Sharma R, Sah S (2020) conducted a study in Department of Radiodiagnosis, Lumbini Medical College and Teaching Hospital, Palpa, to assess sexual dimorphism using morphometric maxillary sinus measurements through CT scan. They analyzed this cross-sectional study with CT scan images of 80 patients (40 males and 40 females) and measured the maxillary sinus mediolateral (ML), superoinferior (SI), anteroposterior (AP) linear dimensions and volume. The measured parameters were then subjected to Student's t-test to determine mean difference between males and females and discriminative statistical analysis was used to determine gender. They obtained the mean value of maxillary sinus length, width, height and volume in males on both right and left sides to be (3.80±0.175, 3.74±0.209) cm, (2.57±0.317, 2.51±0.295) cm, (3.55±0.338, 3.5±0.286) cm and (17.49±3.909, 16.54±3.274) cm3 respectively and in females (3.67±0.250, 3.64±0.256) cm, (2.37±0.297, 2.34±0.3222) cm, (3.29±0.280, 3.23±0.254) cm and (14.42±2.935, 13.81±2.779) cm3 respectively. Their discriminative analysis showed that the accuracy of maxillary sinus measurements was 72.5% in females and 75% of males (overall accuracy = 73.8%).[70]

Sathawane S R, Sukhadeve A V, Chandak M R, Lanjekar A B, Moon GV (2020) conducted a study to determine sex by MS measurements using CBCT scans and discriminant function. They compared the MS dimensions in males and females by sixty CBCT scans showing bilateral MSs of 30 males and 30 females were retrieved and evaluated and the parameters such as width, length, and height were measured and recorded. They analyzed the data using unpaired *t*-test and discriminant function analysis to assess sexual dimorphism. They observed statistically significant differences between males and females in respect to the MS height and length on both the right and left MSs, whereas statistically significant difference were observed in respect to width only on the right MS. The accuracy rate of sex determination was 73% in males and 69% in females, with overall accuracy of 71%. The most pronounced parameter in differentiation of sex is the MS height.[71]

4. MATERIALS AND METHOD

This study was conducted in Department of Oral Medicine and Radiology of Babu Banarasi Das College of Dental Sciences, Lucknow (UP) in collaboration with Department of Trauma Surgery, KGMU, Lucknow. Ethical clearance for the study was obtained from the institutional ethical committee (IEC Code-09)(BBDCODS/01/2019) in accordance with the declaration of Helsinky, research involving human subjects.

The study sample consisted of 60 ((30 males and 30 females) patients from both genders who were advised 3D CT Reconstruction of face for various indications in Department of Radiology, KGMU. The subjects were in the age range of 20 years to 60 years.

Eligibility Criteria:

Inclusion criteria

- Subjects of either gender aged between 20 years to 60 years.
- Subjects with no asymmetry of skull on the 3D CT Reconstructed image.
- Radiographic images in which the borders of maxillary sinus are distinct, free of artifact at the site of measurement.

Exclusion Criteria

- Any pathology or congenital anomaly in the skull that could affect the interpretation of the radiographic image.
- Any fracture line due to trauma within 1 cm of anatomical points used for measuring the dimensions of maxillary sinus.
- Subjects who have undergone surgical procedures which could affect the morphometric measurements.

Sampling Method

- The study sample was randomly selected and consisted of 60 patients (30 males and 30 females) within the age group of 20-60 years who underwent 3D CT Facial Reconstruction for various indications in Department of Radiology, KGMU, Lucknow.The subjects were selected according to the inclusion and exclusion criterion. The collected data was tabulated on spread sheets and subjected to statistical analysis.

Materials and Equipments

Used in the study with specifications and Company

1. Digital 3 Dimensional Reconstruction Computed Tomograph
   Product name – Siemens Somatom definition AS
   Control system – VA48A_SP5_20180301
2. Syngo CT VA48A software

Methodology:

In the present study, all the subjects fulfilling the above criteria were enrolled for the digital assessment of the maxillary sinus dimensions.

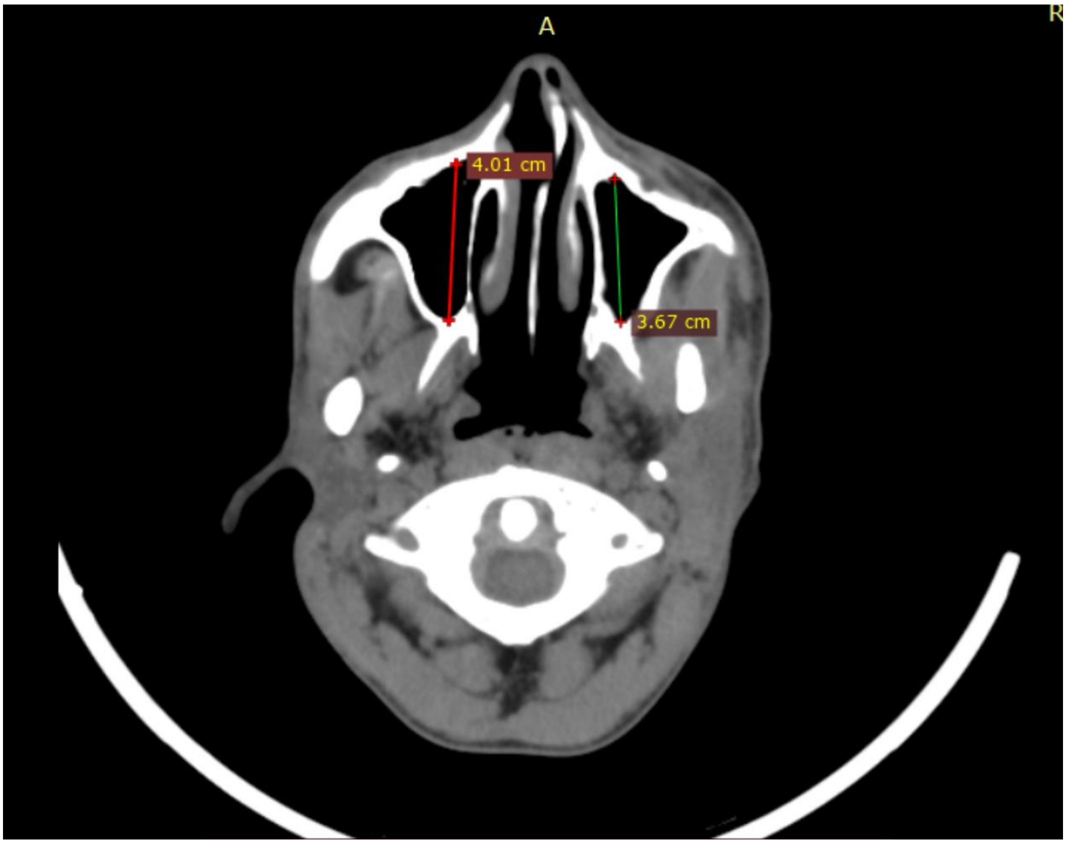
For gender determination

- 3D Computed Tomography Scan were viewed digitally. Measurements were made using the reference lines drawn from anatomical landmarks.
- Four measurements were made on every CT scan on both sides digitally:

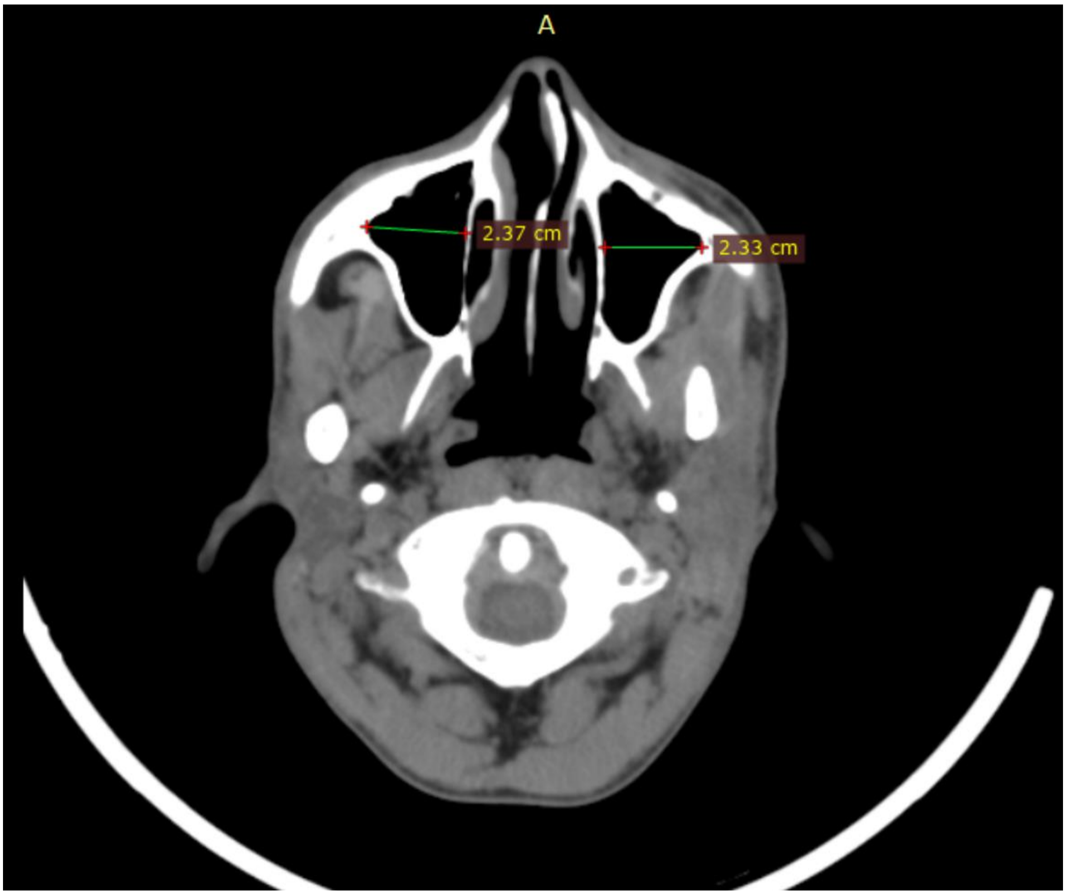
1. The maximum Superoinferior dimension on coronal acquired image which is defined as the maximum distance between the upper and lower sinus wall borders.
2. The maximum medio-lateral dimension on axial acquired image which is defined as the maximum distance measured by a perpendicular dropped

from the outermost point on lateral wall of the maxillary sinus to its medial wall on the largest section.

3. The maximum anteroposterior dimension on axial reconstructed image which is defined as the maximum distance between the anterior and posterior sinus walls on the largest section.
4. The maximum volume of the maxillary sinus on both sides using SYNGO CT VA48A software on the console of siemens 128 slice CT scan from the 3D image

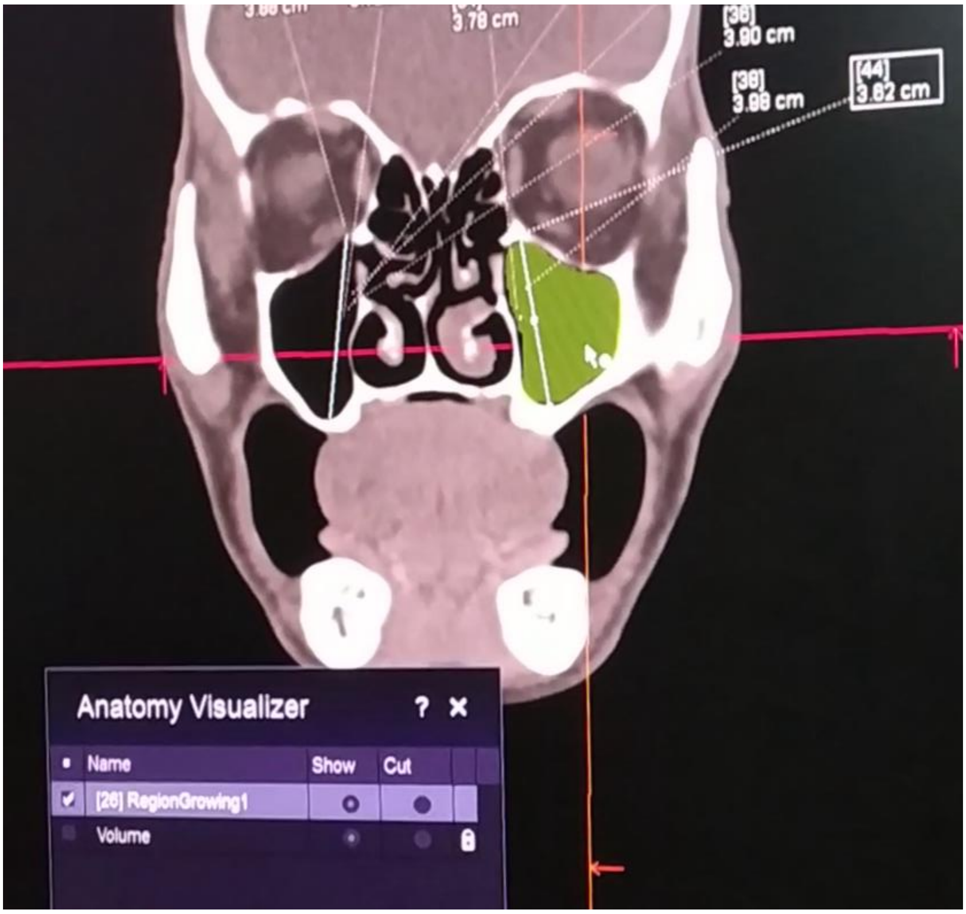


Photograph 3 : Anteroposterior dimension of maxillary sinus of right and left side on Ct scan



Photograph 4 : Mediolateral dimension of maxillary sinus of right and left side on Ct scan

Photograph 5 : Superoinferior dimension of maxillary sinus of right and left side on Ct scan



Photograph 6 : Volume of maxillary sinus on Ct scan

5. RESULTS AND OBSERVATIONS

The present study assesses the accuracy of morphometric evaluation of maxillary sinus using 3D CT reconstruction as a diagnostic parameter for gender determination. Total 60 subjects, 30 males and 30 females, age between 20-60 yrs were recruited. The outcome measures of the study were right and left maxillary sinus dimension (superoinferior, medio-lateral, anteroposterior, and volume). The outcome measures viz. superoinferior, medio-lateral, anteroposterior were measured in millimeter (mm) and volume in cube centimeter (cm^3). The objective of the study was to determine the diagnostic accuracy of right and left maxillary sinus dimension in estimation of gender.

Outcome measures

A. Right Maxillary Sinus Dimension

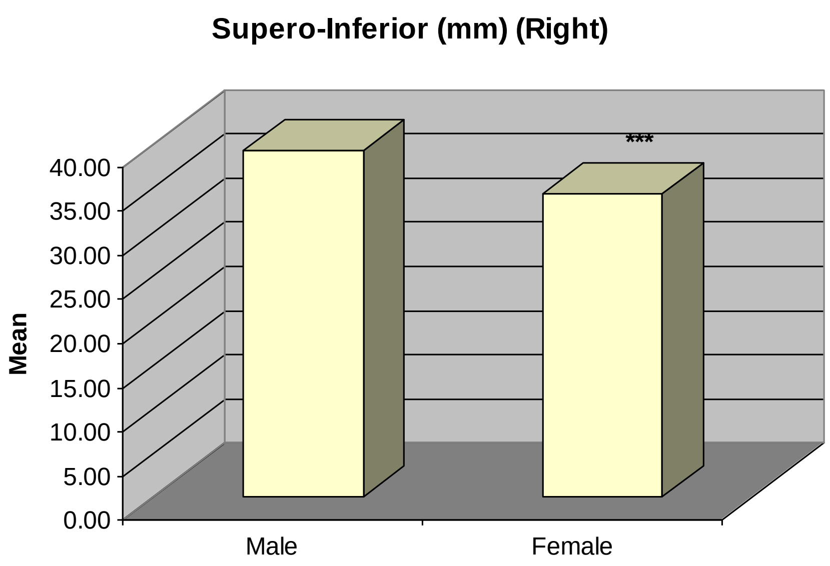
The maxillary sinus dimension (superoinferior, medio-lateral, anteroposterior and volume) of two groups (male and female) at right side is summarized in Table 1 and also shown in Fig. 1-4, respectively. The mean maxillary sinus dimension at right side of female was comparatively lower than male.

Comparing the mean maxillary sinus dimension at right side between two groups, Student's t test showed significantly ($P < 0.001$) different and lower superoinferior (39.22 ± 2.55 vs. 34.29 ± 3.17, diff=4.93, t=6.64, P <0.001), medio-lateral (28.49 ± 3.12 vs. 24.01 ± 2.14, diff=4.48, t=6.48, P <0.001), anteroposterior (39.95 ± 2.06 vs. 36.23 ± 2.99, diff=3.73, t=5.62, P <0.001) and volume (14.88 ± 1.99 vs. 9.95 ± 1.60, diff=4.94, t=10.60, P <0.001) in female as compared to male. Further, these lowered by 12.57, 15.73, 9.33 and 33.17% respectively in female as compared to male.

Table 1: Right maxillary sinus dimension of two groups

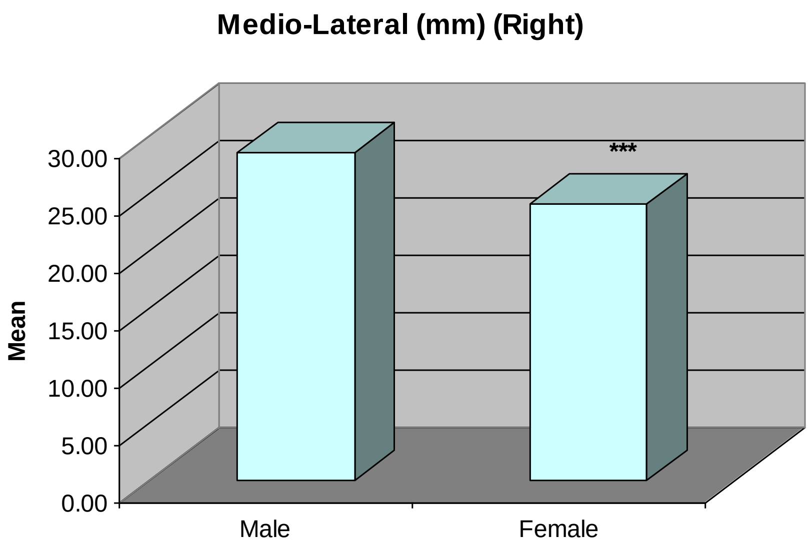
Variable	Male (n=30)	Female (n=30)	Mean diff (%)	t value	*P* value
Superoinferior (mm)	39.22 ± 2.55	34.29 ± 3.17	4.93 (12.57)	6.64	< 0.001
Medio-lateral (mm)	28.49 ± 3.12	24.01 ± 2.14	4.48 (15.73)	6.48	< 0.001
Anteroposterior (mm)	39.95 ± 2.06	36.23 ± 2.99	3.73 (9.33)	5.62	< 0.001
Volume (cm^3)	14.88 ± 1.99	9.95 ± 1.60	4.94 (33.17)	10.60	< 0.001

The right maxillary sinus dimension of two groups were summarized in Mean ± SD and compared by Student's t test (t value).



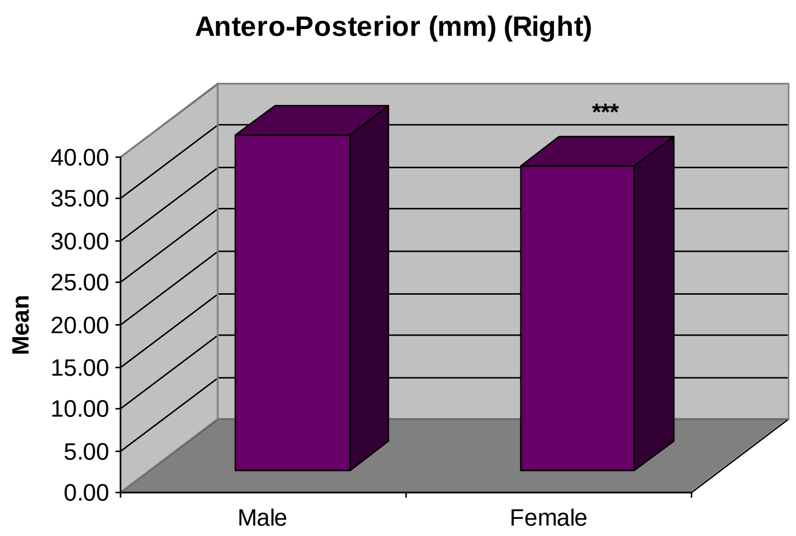
***$P < 0.001$- as compared to Male

Graph. 1. Bar graphs showing comparison of difference in mean superoinferior at right side of two groups.



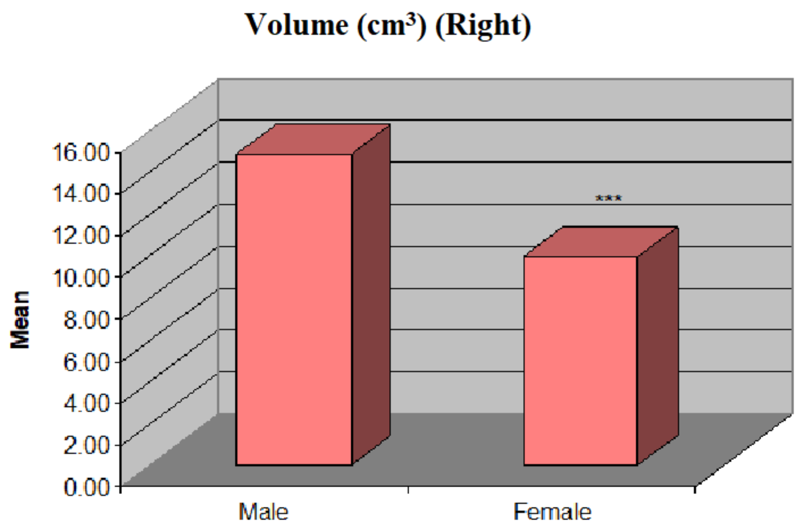
***$P < 0.001$- as compared to Male

Graph 2. Bar graphs showing comparison of difference in mean medio-lateral at right side of two groups.



***$P < 0.001$- as compared to Male

Graph 3. Bar graphs showing comparison of difference in mean anteroposterior at right side of two groups.



***$P < 0.001$- as compared to Male

Graph 4. Bar graphs showing comparison of difference in mean volume at right side of two groups.

B. Left Maxillary Sinus Dimension

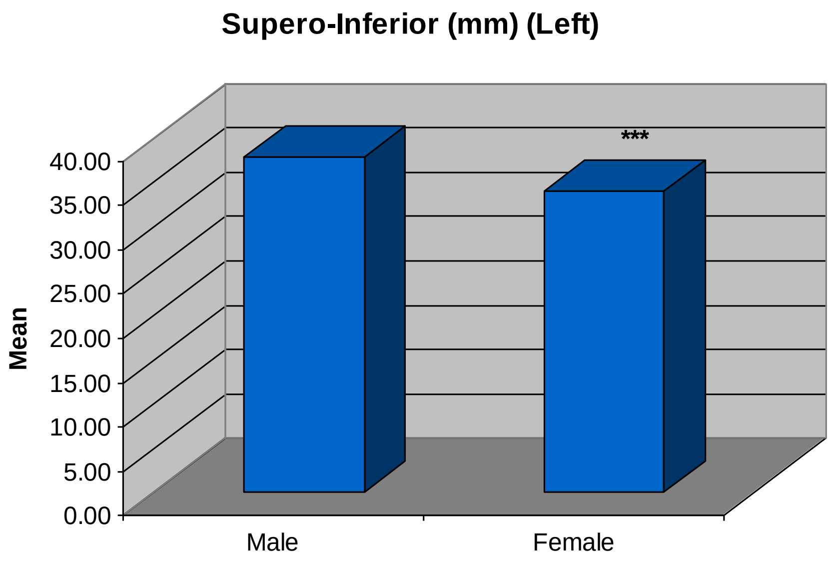
The maxillary sinus dimension (superoinferior, medio-lateral, anteroposterior and volume) of two groups (male and female) at left side is summarized in Table 2 and also shown in Fig. 5-8, respectively. Like right, the mean maxillary sinus dimension at left side was also comparatively lower in female than male.

Comparing the mean maxillary sinus dimension at left side between two groups, Student's t test showed significantly ($P < 0.001$) different and lower superoinferior (37.81 ± 3.19 vs. 33.92 ± 2.95, diff=3.89, t=4.90, P <0.001), medio-lateral (28.57 ± 3.07 vs. 23.48 ± 2.90, diff=5.09, t=6.59, P <0.001), anteroposterior (40.37 ± 1.98 vs. 37.07 ± 1.76, diff=3.30, t=6.83, P <0.001) and volume (14.54 ± 2.18 vs. 9.88 ± 1.80, diff=4.66, t=9.01, P <0.001) in female as compared to male. Further, these lowered by 10.29, 17.81, 8.18 and 32.05% respectively in female as compared to male.

Table 2: Left maxillary sinus dimension of two groups.

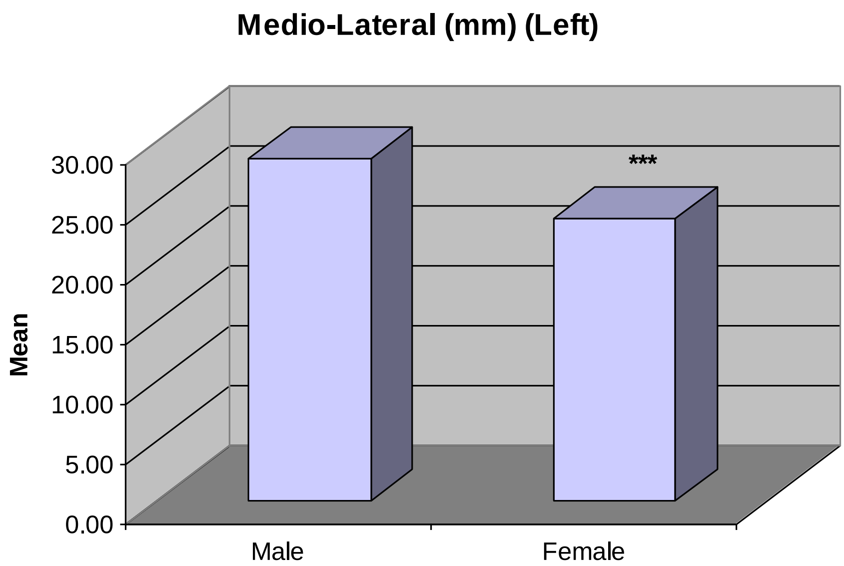
Variable	**Male (n=30)**	**Female (n=30)**	**Mean diff (%)**	**t value**	***P* value**
Superoinferior (mm)	37.81 ± 3.19	33.92 ± 2.95	3.89 (10.29)	4.90	< 0.001
Medio-lateral (mm)	28.57 ± 3.07	23.48 ± 2.90	5.09 (17.81)	6.59	< 0.001
Anteroposterior (mm)	40.37 ± 1.98	37.07 ± 1.76	3.30 (8.18)	6.83	< 0.001
Volume (cm^3)	14.54 ± 2.18	9.88 ± 1.80	4.66 (32.05)	9.01	< 0.001

The left maxillary sinus dimension of two groups were summarized in Mean ± SD and compared by Student's t test (t value).



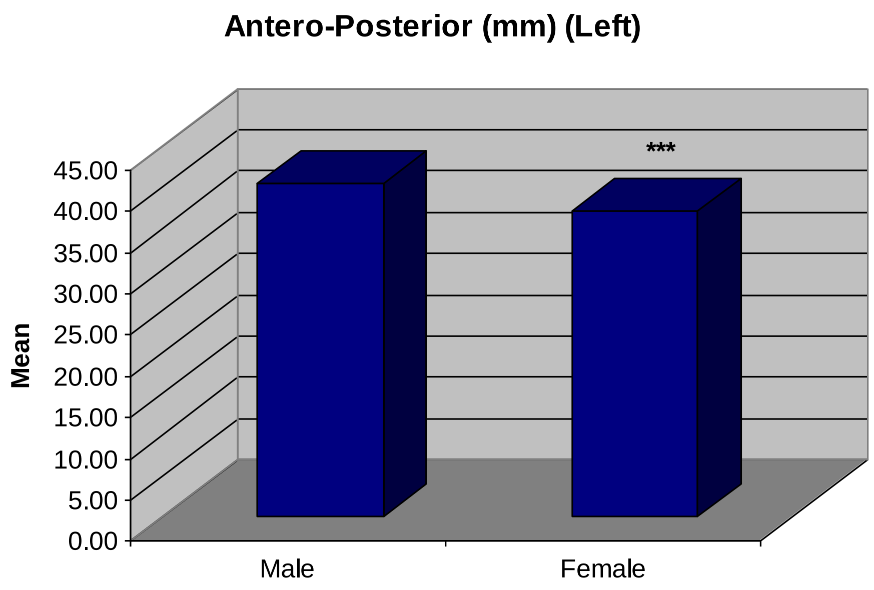
***$P < 0.001$- as compared to Male

Graph 5. Bar graphs showing comparison of difference in mean superoinferior at left side of two groups.



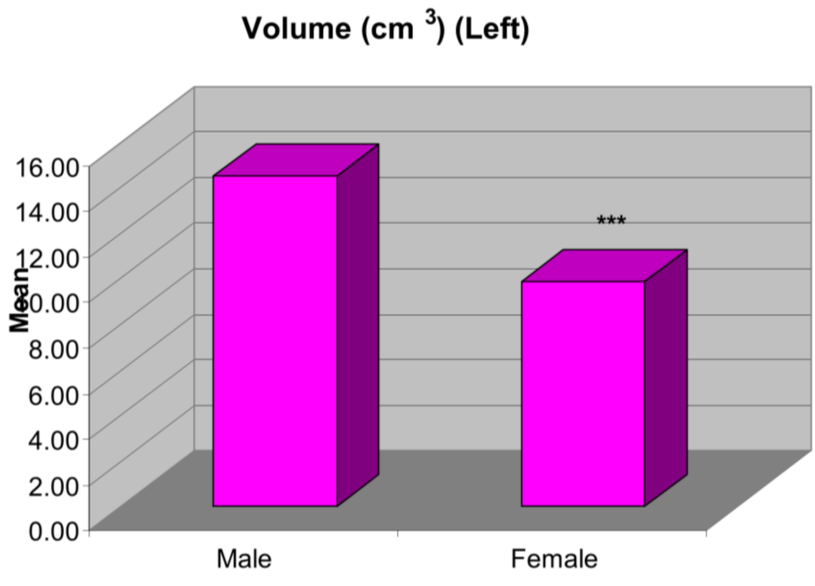
***$P < 0.001$- as compared to Male

Graph 6. Bar graphs showing comparison of difference in mean medio-lateral at left side of two groups.



***$P < 0.001$- as compared to Male

Graph 7. Bar graphs showing comparison of difference in mean anteroposterior at left side of two groups.



***$P < 0.001$- as compared to Male

Graph 8. Bar graphs showing comparison of difference in mean volume at left side of two groups.

Correlation

I. Male

The inter-correlation of right and left maxillary sinus in male subjects is summarized in Table 3. In Male, Pearson correlation analysis showed a significant ($P < 0.05$ or $P < 0.01$ or $P < 0.001$) and positive (direct) correlation between right superoinferior and right volume (r=0.47, $P < 0.01$), right superoinferior and left superoinferior (r=0.47, $P < 0.01$), right medio-lateral and right volume (r=0.78, $P < 0.001$), right medio-lateral and left medio-lateral (r=0.60, $P < 0.001$), right medio-lateral and left volume (r=0.47, $P < 0.01$), right anteroposterior and right volume (r=0.42, $P < 0.05$), right anteroposterior and left superoinferior (r=0.44, $P < 0.05$), right volume and left superoinferior (r=0.44, $P < 0.05$), right volume and left medio-lateral (r=0.46, $P < 0.05$), right volume and left volume (r=0.59, $P < 0.01$), left superoinferior and left volume (r=0.59, $P < 0.01$), and left medio-lateral and left volume (r=0.72, $P < 0.001$) indicating that increase in one variable may be directly associated to increase in other variable or *visa-a-versa*. However, other variables did not correlate ($P > 0.05$) well with other.

II. Female

The inter-correlation of right and left maxillary sinus in female subjects is summarized in Table 4. In female, Pearson correlation analysis showed a significant ($P < 0.05$ or $P < 0.01$ or $P < 0.001$) and positive (direct) correlation between right superoinferior and right volume (r=0.68, $P < 0.001$), right superoinferior and left superoinferior (r=0.73, $P < 0.001$), right medio-lateral and right volume (r=0.62, $P < 0.001$), right medio-lateral and left medio-lateral (r=0.68, $P < 0.001$), right medio-lateral and left anteroposterior (r=0.37, $P < 0.05$), right medio-lateral and left volume (r=0.66, $P < 0.001$), right anteroposterior and right volume (r=0.42, $P < 0.05$), right volume and left superoinferior (r=0.48, $P < 0.01$), right volume and left volume (r=0.46, $P < 0.05$), left superoinferior and left volume (r=0.59, $P < 0.01$), left medio-lateral and left volume (r=0.86, $P < 0.001$), and left anteroposterior and left volume (r=0.52, $P < 0.01$) suggesting that increase in one variable may be directly associated to increase in other variable or *visa-a-versa*. However, other variables did not correlate ($P > 0.05$) well with other.

Table 3: Inter-correlation of right and left maxillary sinus in male subjects (n=30) by Pearson correlation analysis

Variable	*Superoinferior (Right)*	*Medio-Lateral (Right)*	*Anteroposterior (Right)*	*Volume (Right)*	*Superoinferior (Left)*	*Medio-Lateral (Left)*	*Anteroposterior (Left)*	*Volume (Left)*
Superoinferior (Right)	1.00							
Medio-Lateral (Right)	-0.03^{ns}	1.00						
Anteroposterior (Right)	0.04^{ns}	0.02^{ns}	1.00					
Volume (Right)	0.47^{**}	0.78^{***}	0.42^{*}	1.00				
Superoinferior (Left)	0.47^{**}	0.05^{ns}	0.44^{*}	0.44^{*}	1.00			
Medio-Lateral (Left)	0.14^{ns}	0.60^{***}	-0.20^{ns}	0.46^{*}	-0.01^{ns}	1.00		
Anteroposterior (Left)	-0.16^{ns}	0.06^{ns}	0.17^{ns}	0.05^{ns}	0.04^{ns}	-0.01^{ns}	1.00	
Volume (Left)	0.32^{ns}	0.47^{**}	0.16^{ns}	0.59^{**}	0.59^{**}	0.72^{***}	0.36^{ns}	1.00

ns- $P > 0.05$, *****- $P < 0.05$, ******- $P < 0.01$ and *******- $P < 0.001$

Table 4: Inter-correlation of right and left maxillary sinus in female subjects (n=30) by Pearson correlation analysis

Variable	*Superoinferior (Right)*	*Medio-Lateral (Right)*	*Anteroposterior (Right)*	*Volume (Right)*	*Superoinferior (Left)*	*Medio-Lateral (Left)*	*Anteroposterior (Left)*	*Volume (Left)*
Superoinferior (Right)	1.00							
Medio-Lateral (Right)	0.19^{ns}	1.00						
Anteroposterior (Right)	-0.06^{ns}	-0.12^{ns}	1.00					
Volume (Right)	0.68***	0.62***	0.42*	1.00				
Superoinferior (Left)	0.73***	0.23^{ns}	-0.17^{ns}	0.48**	1.00			
Medio-Lateral (Left)	0.03^{ns}	0.68***	-0.35^{ns}	0.22^{ns}	0.17^{ns}	1.00		
Anteroposterior (Left)	-0.06^{ns}	0.37*	0.32^{ns}	0.33^{ns}	0.05^{ns}	0.34^{ns}	1.00	
Volume (Left)	0.35^{ns}	0.66***	-0.24^{ns}	0.46*	0.59**	0.86***	0.52**	1.00

ns- $P > 0.05$, *****- $P < 0.05$, ******- $P < 0.01$ and *******- $P < 0.001$

Diagnostic

I. Right Maxillary Sinus Dimension

The diagnostic accuracy (sensitivity and specificity) of right maxillary sinus dimension (superoinferior, medio-lateral, anteroposterior and volume) in estimation of gender is evaluated using ROC curve analysis and summarized in Table 5 and also depicted in Fig. 9-12, respectively. The ROC curve analysis showed significant diagnostic of superoinferior (AUC=0.877, Z=8.16, $P < 0.001$), medio-lateral (AUC=0.856, Z=7.17, $P < 0.001$), anteroposterior (AUC=0.854, Z=7.10, $P < 0.001$), and volume (AUC=0.964, Z=18.51, $P < 0.001$).

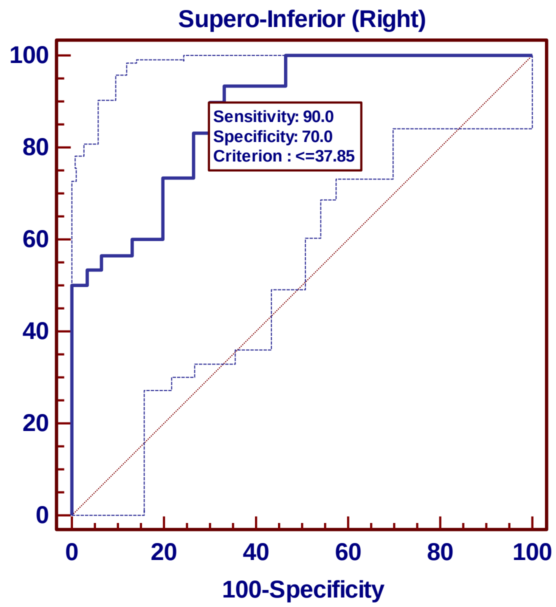
Further, at cuff-off (criterion) value of ≤ 37.85, ≤ 27.56, ≤ 40.01 and ≤ 10.93 these respectively discriminating the two groups of genders (i.e. male and female) with 90.00% sensitivity (95% CI: 73.4-97.8) and 70.00% specificity (95% CI: 50.6-85.2), 100.00% sensitivity (95% CI: 88.3-100.0) and 63.33% specificity (95% CI: 43.9-80.0), 100.00% sensitivity (95% CI: 88.3-100.0) and 56.67% specificity (95% CI: 37.4-74.5), and 76.67% sensitivity (95% CI: 57.7-90.0) and 100.00% specificity (95% CI: 88.3-100.0), respectively.

Further, the diagnostic accuracy of volume was found to the highest followed superoinferior, medio-lateral and anteroposterior, the least.

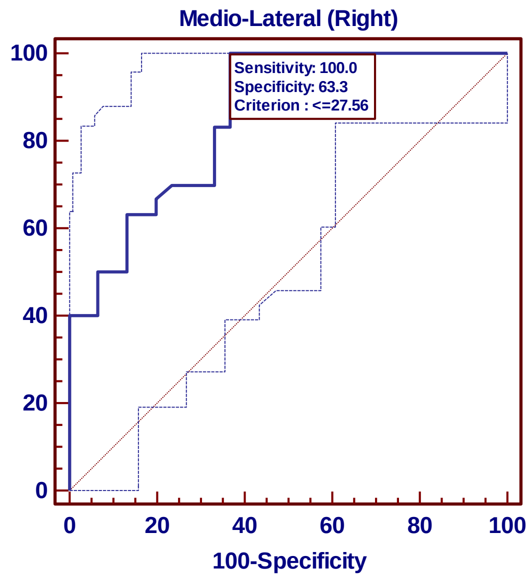
Table 5: Diagnostic of right maxillary sinus dimension in estimation of gender using ROC curve analysis.

Variable	**Cut-off value**	**AUC**	**Z value**	***P* value**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**+ PV**	**-PV**
Superoinferior (mm)	≤ 37.85	0.877	8.16	< 0.001	90.00 (73.4-97.8)	70.00 (50.6-85.2)	75.0	87.5
Medio-lateral (mm)	≤ 27.56	0.856	7.17	< 0.001	100.00 (88.3-100.0)	63.33 (43.9-80.0)	73.2	100.0
Anteroposterior (mm)	≤ 40.01	0.854	7.10	< 0.001	100.00 (88.3-100.0)	56.67 (37.4-74.5)	69.8	100.0
Volume (cm^3)	≤ 10.93	0.964	18.51	< 0.001	76.67 (57.7-90.0)	100.00 (88.3-100.0)	100.0	81.1

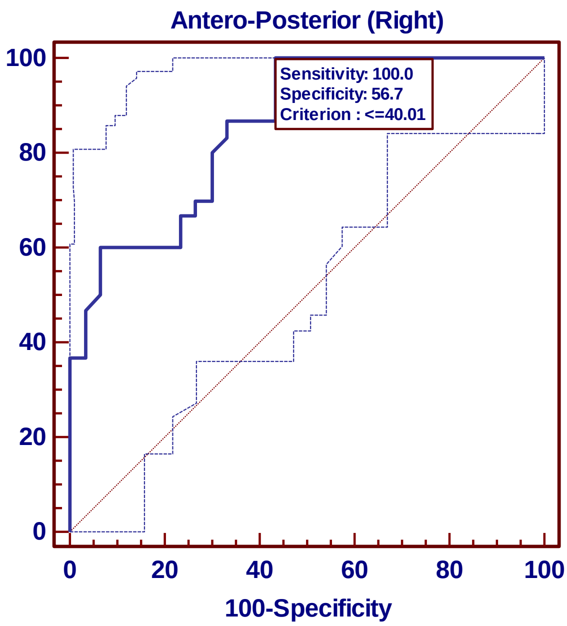
AUC: area under the curve, **CI:** confidence interval, **+PV:** positive predictive value, **-PV:** negative predictive value



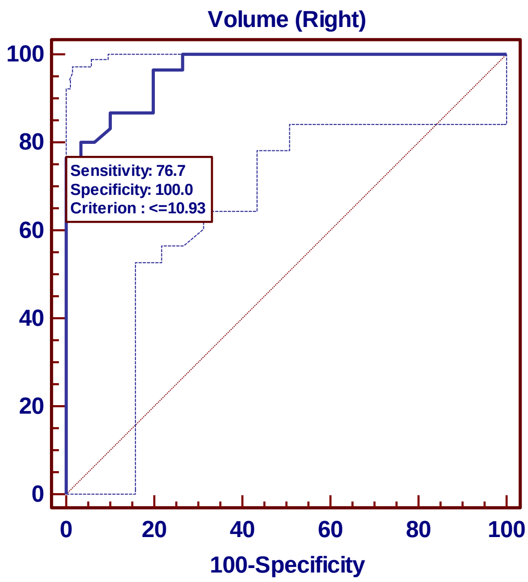
Graph 9. Diagnostic accuracy of right superoinferior in estimation of gender using ROC curve analysis.



Graph 10. Diagnostic accuracy of right medio-lateral in estimation of gender using ROC curve analysis.



Graph 11. Diagnostic accuracy of right anteroposterior in estimation of gender using ROC curve analysis.



Graph 12. Diagnostic accuracy of right volume in estimation of gender using ROC curve analysis.

II. Left Maxillary Sinus Dimension

The diagnostic accuracy (sensitivity and specificity) of left maxillary sinus dimension (superoinferior, medio-lateral, anteroposterior and volume) in estimation of gender is evaluated using ROC curve analysis and summarized in Table 6 and also depicted in Fig. 13-16, respectively. The ROC curve analysis showed significant diagnostic of superoinferior (AUC=0.808, Z=5.45, $P < 0.001$), medio-lateral (AUC=0.897, Z=9.40, $P < 0.001$), anteroposterior (AUC=0.891, Z=9.00, $P < 0.001$), and volume (AUC=0.959, Z=17.15, $P < 0.001$).

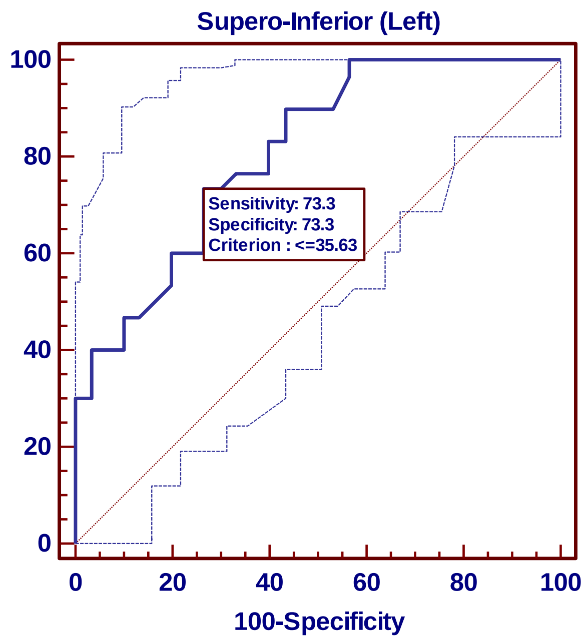
Further, at cuff-off (criterion) value of ≤ 35.63, ≤ 24.35, ≤ 39.10 and ≤ 10.59 these respectively discriminating the two groups of genders (i.e. male and female) with 73.33% sensitivity (95% CI: 54.1-87.7) and 73.33% specificity (95% CI: 54.1-87.7), 70.00% sensitivity (95% CI: 50.6-85.2) and 100.00% specificity (95% CI: 88.3-100.0), 90.00% sensitivity (95% CI: 73.4-97.8) and 76.67% specificity (95% CI: 57.7-90.0), and 76.67% sensitivity (95% CI: 57.7-90.0) and 100.00% specificity (95% CI: 88.3-100.0), respectively.

Further, the diagnostic accuracy of volume was found to the highest followed medio-lateral, anteroposterior and superoinferior, the least.

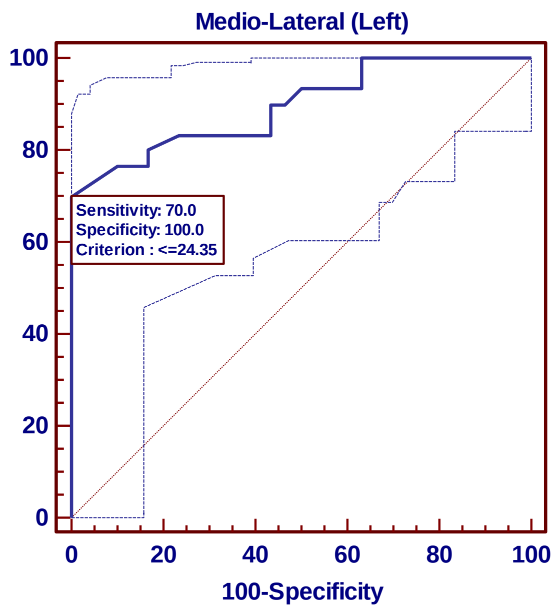
Table 6: Diagnostic of left maxillary sinus dimension in estimation of gender using ROC curve analysis.

Variable	**Cut-off value**	**AUC**	**Z value**	***P* value**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**+ PV**	**-PV**
Superoinferior (mm)	≤ 35.63	0.808	5.45	< 0.001	73.33 (54.1-87.7)	73.33 (54.1-87.7)	73.3	73.3
Medio-lateral (mm)	≤ 24.35	0.897	9.40	< 0.001	70.00 (50.6-85.2)	100.00 (88.3-100.0)	100.0	76.9
Anteroposterior (mm)	≤ 39.10	0.891	9.00	< 0.001	90.00 (73.4-97.8)	76.67 (57.7-90.0)	79.4	88.5
Volume (cm^3)	≤ 10.59	0.959	17.15	< 0.001	76.67 (57.7-90.0)	100.00 (88.3-100.0)	100.0	81.1

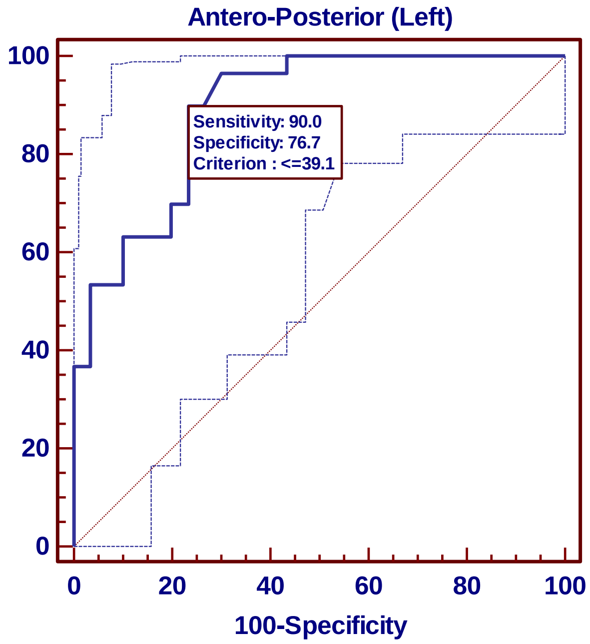
AUC: area under the curve, **CI:** confidence interval, **+PV:** positive predictive value, **-PV:** negative predictive value



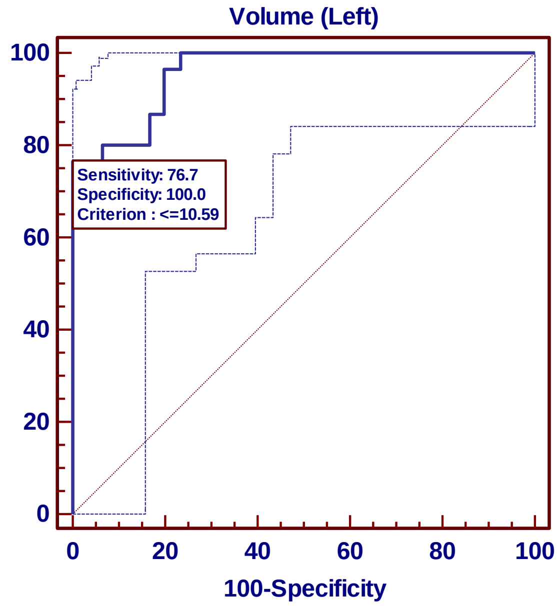
Graph 13. Diagnostic accuracy of left superoinferior in estimation of gender using ROC curve analysis.



Graph 14. Diagnostic accuracy of left medio-lateral in estimation of gender using ROC curve analysis.



Graph 15. Diagnostic accuracy of left anteroposterior in estimation of gender using ROC curve analysis.



Graph 16. Diagnostic accuracy of left volume in estimation of gender using ROC curve analysis.

6. DISCUSSION

Forensic science deals with identification of human body or remains after death, which is difficult to perform and is mandatory by law and in compliance with social norms. Forensic science-based evidence is accepted in a judicial setting by the court and plays a significant role in the identification of individuals who cannot be identified visually or by other simple means. Determination of gender from remains of human skeleton is an important forensic procedure which is the first step followed by age and stature, as both are dependent on gender.

Gender determination can be done with 100 % accuracy if the skeleton exists completely however victim identification in mass disasters like airplane crashes, terrorist attacks, landslides, explosions and warfare is difficult. The gender determination in such cases is 98 % when there is existence of pelvis and cranium, 95% with only pelvis and long bones and 80 – 90% with only long bones. [52] But in many instances these bones are recovered either in a fragmented or incomplete state where gender determination is extremely difficult to perform. One such body part which is recovered intact in explosions, warfare, and other mass disasters such as aircraft crashes, when other bones are badly disfigured, is maxilla. This uniqueness is attributed to the fact that maxillary sinus is dense enough to be recovered completely intact even in catastrophes like explosions, natural calamities etc. [11]

Many radiographic imaging techniques have been employed to study the maxillary sinus. These include the 2-dimensional techniques such as OPG, Lateral Cephalogram etc. however these modalities have certain inherent limitations, such as unequal magnification and geometric distortion across the image layer, leading to an inaccurate depiction of anatomy and pathology as well as unreliable measurement accuracy. Hence in the present study the radiographic methodology utilised for morphometric evaluation of maxillary sinus was 3D CT as this technique as it provides a more detailed anatomic picture for better evaluation of the sinuses.

Hence a hypothesis was made for this study which aimed at documenting the accuracy of morphometric evaluation of maxillary sinus using 3D CT for determination of genderas a forensic tool. In this study, a total of 60 CT images (30 males and 30 females) were included. Different parameters of maxillary sinus were estimated for gender determination. The parameters include the maximum Superoinferior dimension of right and left maxillary sinus in coronal multiplanar reformatted [MPR] image, maximum medio-lateral dimension of right and left maxillary sinus in coronal MPR image, maximum anteroposterior dimension of right and left maxillary sinus in axial MPR image, volume of right and left maxillary sinus using "Region Growing" function of SYNGO CT VA48A software on Siemens 128 slice CT scan console from 3D image.

GENDER DETERMINATION

A. RIGHT MAXILLARY SINUS DIMENSION

Superoinferior Dimension

The present study recorded statistically significant result for superoinferior dimension of the right maxillary sinus for both males and females and concluded that the length of the dimension in males was 15% larger than in females. The mean value of the measurement of this dimension in male was found out to be 39.22 ± 2.55 mm and in females, it was found out to be 34.29 ± 3.17 mm. (Table 1)

The findings in the present study have been supported by several other studies done recently. One such study by **S Ramhari Sathawane et al**, **(2020)** [71] reported mean value in males to be 37.57 ± 4.66 mm and 31.52 ± 2.61 mm in females. This was consistent with the ~15% difference in the measurement between males and females as reported in the current study. Another prominent study by **Sanda Usharani et al., (2017)** [64] reported mean value in males to be 38.9 ± 1.4 mm and in females to be 32.1 ± 0.5mm, further supporting the findings presented in the current study. The study by **Santosh kandel et al**., **(2020)** [70] also found similar differences in the mean values and reported mean value in males to be 35.50 ± 3.30 mm and 32.9 ± 2.80 mm in females.

In contrast, a few studies have also reported statistically insignificant difference between the measurement of the dimension in males and females. One such study by **Ayeesha Urooge et al**., **(2017)** [59] reported mean value in males to be 35.5 ± 5.3 mm and 34.0 ± 4.4 mm in females. Another study by **Nabila N Sheikh et al., (2018)** [62] further contrasted the findings of the present study and reported a slightly larger mean measurement of the superoinferior dimension of the right maxillary sinus in females compared to males. The study reported mean value of 25.7 ± 5.64 mm in males and 26.2 ± 4.42 mm in females. The difference was small enough to safely consider it statistically insignificant at p value 0.08.

Mediolateral Dimension

The present study found statistically significant result in relation to the mediolateral dimension of the right maxillary sinus in males and females. The measurements in males were found to be, on average, 20% larger than the measurements recorded in females. The mean values in males were found to be 28.49 ± 3.12 mm while in females, they were found to be 24.01 ± 2.14 mm. (Table 1)

These findings are corroborated by several studies done over the last 10 years. The study by S **Ramhari Sathawane et al**, **(2020)** [71] reported similar differences between the male and female mediolateral dimension of the right maxillary sinus, with the dimension in male found to be larger than females, although by a similar extent. This study reported mean values in males to be 28.7 ± 2.87 mm and in females to be 26.77 ± 3.13 mm which was found to be highly statistically significant at p value 0.008. The mean value of the dimensions recorded in males in this study was in line with the values recorded in the present study, however, the mean value in female differed by approximately 10%. Another study by **Santosh kandel et al., (2020)** [70] reported smaller dimensions on the right maxillary sinus in both males and females, when compared to the findings in the current study. This study reported mean values in males to be 25.7 ± 0.31 mm and 23.70 ± 2.9 mm in females. However, these were still in line with the statistically significant differences in the dimensions observed between males and females in the current study. A study done by **Sanda Usharani et al., (2017)** [64] reported much larger mean values in both males and females, while still showing similar differences in the dimensions between males and females as found in the current study. This study reported mean values in males to be 41.1 ± 1.3 mm and 37.9 ± 1.2 mm in females which was statistically significant. Another study worth mentioning was done by **Shehnaz S et al., (2016)** [51] which reported mean values in males to be 29.78 ± 2.25 mm and 23.80 ± 5.04 mm in females .These findings were very closely in line with the findings of the present study, both in terms of the values observed in males and females, and the difference between the values in the two genders.

It is also worth mentioning that there have been at least two studies of significance which have reported contrasting results compared to the findings of the present study. These studies reported larger values in mediolateral dimension of the right maxillary sinus in females compared to males. The study by **Ayeesha Urooge et al.,(2017)** [59] reported mean values in males to be 24.2 ± 4.1 mm and in females to be 25.7 ± 4.1 mm. Similarly, another study **by Nabila N Sheikh et al., (2018**) [62] reported the mean values in males to be 23.52 ± 5.50 mm and 24.54 ± 6.12 mm in females. Both these studies reported a difference of less than 5% between the measurement of the right mediolateral maxillary sinus in males and females.

Anteroposterior Dimension

In the present study of the anteroposterior dimension of the right maxillary sinus in males was found to be 39.95 ± 2.06 mm and 36.23 ± 2.99 mm in females. There was a 10% difference on average between the measurements of the anteroposterior dimension in males and females which was found to be statistically significant. (Table 1)

There have been several studies done recently which provide supporting evidence for the observations made in this study. A prominent study by **S Ramhari Sathawane et al, (2020)** [71] also observed statistically significant result and reported mean value of 39.61 ± 3.29 mm and 36.02 ± 2.62 mm in females. In accordance with the findings of the present study, the right maxillary sinus showed larger anteroposterior dimension in males when compared to females. Similarly, the study by **Shehnaz S et al., (2016)** [51] provides further supporting evidence for the findings of this study. This study also stated that the right maxillary sinus showed larger dimension in males (40.22 ± 3.02 mm) when compared to females (35.66 ± 3.02 mm). Another such study drawing the same conclusion was done by **Sanda Usharani et al., (2017)** [64] which reported mean value in males to be 43.2 ± 0.9 mm and in females, it was reported to be 38.8 ± 0.4 mm. **Mukul Prabhat et al., (2016)** [3] did a study in 2016 which also concluded that the male anteroposterior dimension of the right maxillary dimension was larger in males when compared to females, based on the recorded observations. This study reported mean value of 42.6 ± 3.79 mm in males and 36.00 ± 4.09 mm in females. The study by **Ranjeeth kumar Kanthem , (2015)** [11] also found a larger difference in dimension between the anteroposterior dimension in males and females. This study reported mean value in males to be 37.6 ± 3.52 mm and in females, it was reported to be 31.2 ± 1.4 mm.

It is worth mentioning that there have also been a few studies recently which have reported statistically insignificant differences between the anteroposterior dimension of right maxillary sinus in males and females. While all these studies still reported a slightly larger dimension in males when compared to females, the difference was small enough to draw any concrete conclusions. A study by **Ayeesha Urooge et al., (2017)** [59] reported mean value in males to be 38.1 ± 3.3 mm and in females, it was reported to be 37.8 ± 2.3 mm. They found this observation to be statistically insignificant at p value 0.66. Similarly, the study by **Balaji Babu Bangi et al., (2017)** [57] also found statistically insignificant difference in dimension between males and females. This study reported the mean value in males to be 35.76 ± 4.13 mm and 33.76 ± 4.13 mm in females.

Volume

Based on the observations recorded by the current study, it was concluded that there was a statistically significant difference between the male and female volume of the right maxillary sinus and could be justifiably used as an indicator for sex determination of unknown individual. In the present study, the mean value of the maxillary sinus volume of right side of males was 14.88 ± 1.99 cm3 and 9.95 ± 1.60cm^3. The volume of maxillary sinus was found to be larger in males, with the male volume being larger by 50% of the female volume based on the recorded mean value. (Table 1)

Several studies have done volumetric analysis of the maxillary sinus to demonstrate its use in the determination of the sex of an unknown individual. One such study by **Suwarna Dangore Khasbage et al., (2018)** [61] found a significant degree of difference between the right maxillary sinus volume in males and females and reported mean value in males to be 17.21 ± 6.26cm^3 and in females to be 11.58 ± 4.90cm^3. This study concluded that the volume of the right maxillary sinus could be used as an indicator in the determination of the sex of an unknown individual. Similarly, the study by **Ranjeeth kumar Kenthem et al., (2015)** [11] found significant differences between the volume of right maxillary sinus in the two sexes. This study reported the mean value in males to be 39.93 ± 38.38cm^3 and in females, it was reported to be 21.53 ± 21. 05cm^3. Another study of prominence that concluded that the volume of the right maxillary sinus could be used as a potential indicator to determine the sex of an unknown individual was done by **Sanda Usharani et al., (2017).** [64] This study reported mean value in males to be 34.62 ± 2.18cm^3 and in females, it was reported to be 23.65 ± 1.36cm^3. This study also found a similar degree of difference between the volumes in males and females. **Mukul Prabhat et al., (2016**) [3] published a study in 2016 which reported mean value of volume of right maxillary sinus in males to be 16.63 ± 4.54cm^3 and 11.61 ± 5.65cm^3 in females. The findings of this study were in line with the conclusions drawn by the present study, thus adding further evidence to the findings of the current study.

One of the studies done by **Ayeesha Urooge et al., (2017)** [59] found contrasting evidence and reported slightly larger mean value of volume of right maxillary sinus in females when compared to males. This study reported mean value in males to be 16.74 ± 5.28 cm^3 and in females, it was reported to be 16.89 ± 5.28 cm^3. However, the difference in volume between the two sexes was so small that the study failed to draw any concrete conclusion based on this parameter.\

B. LEFT MAXILLARY SINUS DIMENSION

Superoinferior Dimension

The current study recorded several observations for the superoinferior dimension of the left maxillary sinus in both males and females and found the mean value in males to be 37.81 ± 3.19 mm and 33.92 ± 2.95 mm in females. The findings showed statistically significant result at p value < 0.001ans t value 4.90. The study found that the superoinferior dimension of the left maxillary sinus in males was about 10% larger than in females. (Table 2)

There have been several studies in the recent years supporting the findings of the current study. One such study by **Santosh kandel et al., (2020)** [70] reported mean values in males to be 35.0 ± 2.86 mm and 32.3 ± 2.54 mm in females. The difference in measurement of the dimension between males and females in this study was found to be consistent with the findings of the present study. Another such study supporting the findings of the present study was done by **Mukul Prabhat et al., (2016)** [3]. This study reported the mean values in males to be 36.99 ± 4.45 mm and in females to be 33.11 ± 6.71 mm which was statistically significant as p value was found to be < 0.05. The study by **Balaji Babu Bangi et al., (2017)** [57] also found differences to a similar degree between the superoinferior dimension in males and females. This study reported lower mean values in both males and females compared to the present study. The mean value in males was 31.70 ± 5.02 mm found to be and in 29.31 ± 5.45 mm in females. **Sanda Usharani et al. (2017)** [64] conducted a study in 2017 and reported mean value of 38.8 ± 1.1 mm in males and 31.8 ± 0.4 mm in females, further supporting the findings of the current study.

Another study by **Ranjeeth kumar Kanthem et al, (2015)** [11] reported a difference of over 30% between the measurement of the dimension in males and females. This study reported statistically significant mean value of the measurement in males to be 39.3 ± 3.94 mm and 30.7 ± 3.12 mm in females. Another study by **Shehnaz S et al., (2016)** [51] also reported a similar degree of difference in the measurement of the dimension. This study reported mean values in males to be 39.67 ± 4.17 mm and 30.64 ± 4.24 mm in females. The study by **Suwarna Dangore Khasbage et al., (2018)** [61] large difference between the measurement of superoinferior dimension in males and females. This study reported mean values in males to be 33.3 ± 6.2 mm and 26.6 ± 7.4mm in females which was statistically significant at p value 0.001 which was in accordance with the present study.

However, there have also been a few studies that have reported contrasting evidence of a larger measurement of superoinferior dimension of the left maxillary sinus in females compared to males. A prominent study by **S Ramhari Sathawane et al, (2020)** [71] observed that the female superoinferior dimension of the left maxillary sinus was on average 10% larger than in males. This study reported mean value in males to be 36.79 ± 3.79 mm and 39.92 ± 2.98 mm in females. Another study by **Nabila N Sheikh et al., (2018)** [62] reported a marginal difference in the measurement of the dimension between female and males, although the measurement of the dimension in females was found to be larger. This study reported mean value of in 26.16 ± 6.90 mm males and 26.78 ± 5.57 mm in females.

Mediolateral Dimension

In the present study, the mean value of mediolateral dimension of left maxillary sinus for males and females was 28.57 ± 3.07 and 23.48 ± 2.90, respectively, which was found to be statistically significant at p value < 0.001 and t value 6.48 (Table 2)

Previous other studies have shown similar results and have reported large differences in the left mediolateral dimension of maxillary sinus in males when compared to females as observed in the present study. One such study by **Santosh kandel et al. (2020)** [70] showed the mean value for left mediolateral dimension in males to be 25.1 ± 2.95 mm and females to be 23.4 ± 3.22 mm which was statistically significant at p value 0.016. The findings of the study by **Balaji Babu Bangi et al., (2017)** [57] also supported marginal difference between males and females and reported the mean values of 26.18 ± 5.48 mm in males and 24.43 ± 4.23 mm in females which was found to be statistically significant. **Suwarna Dangore Khasbage et al., (2018)** [61] found out a difference of over 5 mm in the mean values between the male and female left mediolateral sinus dimension. The mean value in males was found out to be 27.3 ± 5.8 mm while in females it was found to be 22.5 ± 4.7 mm and was reported to be statistically significant at p value 0.0001. This evidence is further supported in another study done by **Mukul Prabhat et al., (2016)** [3] which showed a similar significant difference in the left mediolateral dimension between male and female maxillary sinus. This study reported mean values in males to be 27.01 ± 5.04 mm and 23.22 ± 6.21 mm in females. Similar findings supporting a significantly larger left mediolateral dimension in males were also reported by a study by **Shehnaz S et al., (2016)** [51] which observed the mean values in males to be 29.75 ± 2.39 mm and 23.61 ± 4.24 mm in females which was of statistical significance at p value <0.001.

However, a few other studies have reported statistically insignificant difference in the left mediolateral dimension in male maxillary sinus when compared to females. One such study by **S Ramhari Sathawane et al(2020)** [71] found a marginal difference between the mediolateral dimension between males and females. The findings of the study reported a mean value of 28.02 ± 3.03 mm for the left mediolateral dimension in males, while female left mediolateral dimension was found to be marginally lower at 27.42 ± 3.64mm. Their study found this difference to be statistically insignificant at p value 0.49.

In contrast to the findings in the present and above-mentioned studies, there have been a few studies that reported larger mean values for left mediolateral dimension in females when compared to males. A recent study done by **Nabila N Sheikh et al., (2018)** [62] reported a marginally larger left mediolateral dimension in females. This study reported mean values of 22.96 ± 5.59 mm in males and 23.30 ± 5.95 mm in females. Another study supporting this finding was done by **Ayeesha Urooge et al., (2017)** [59], which reported mean values in males to be 24.0 ± 4.3mm and 24.8 ± 4.6 mm in females.

Anteroposterior Dimension

Several observations were recorded by the present study to determine any significant difference between the anteroposterior dimension of the left maxillary sinus between males and females. The present study concluded that the male anteroposterior dimension of the left maxillary sinus was, on average, 10% larger in males when compared to females. The mean value of the recorded observations was statistically significant and was found to be 40.37 ± 1.98 mm in males and 37.07 ± 1.76 mm in females. (Table 2)

Many studies done in the past ten years have analyzed and recorded the measurement of the anteroposterior dimension the left maxillary sinus for both males and females. There have been several studies done recently that support the conclusions drawn by the present study regarding the difference in dimension between the anteroposterior dimension in males and females. One such study of prominence was done by **Sanda Usharani et al., (2017)** [64] which also concluded that male anteroposterior dimension was larger than the female anteroposterior dimension in the left maxillary sinus. This study stated that the mean value in males for the dimension was 42.7 ± 0.3 mm and in females, it was reported to be 38.2 ±

0.8 mm which was found to be statistically significant. Another study by **S Ramhari Sathawane et al, (2020)** [71] lends further supporting evidence to the findings of the present study. This study reported that the mean value in male for the anteroposterior dimension was 38.58 ± 3.42 mm and in females, it was reported to be 38.58 ± 3.42 mm. The study also concluded that the anteroposterior dimension of the left maxillary sinus was larger in males when compared to females, based on the observations recorded by the study. **Shehnaz S et al., (2016)** [51] did a study in 2016 which stated the mean value for left anteroposterior dimension was in males 39.59 ± 2.97 mm and female anteroposterior dimension was 35.12 ± 3.91 mm which was statistically significant at p value <0.001. This study also showed a larger dimension for males when compared to females. The study by **Ranjeeth kumar Kanthem , (2015)** [11]found much larger difference in measurement of the anteroposterior dimension between males and females. This study reported mean value in males to be 37.3 ± 3.79 mm and 31.2 ± 3.12 mm in females at p value <0.00001.

There have also been a few studies that have analyzed the difference in measurement of anteroposterior dimension of left maxillary sinus between males and females but found statistically insignificant. A study by **Ayeesha Urooge et al., (2017)** [59] reported mean value in males to be 37.8 ± 3.3 mm and in females, it was reported to be 37.1 ± 2.9 mm which was statistically insignificant at p value 0.288. Similarly, the study **Balaji Babu Bangi et al., (2017)** [57] reported mean value in males to be 35.59 ± 3.85 mm and 33.84 ± 3.88 mm in females, concluding that the difference between male and female anteroposterior dimension of the left maxillary sinus was statistically insignificant.

Volume

The present study tried to evaluate whether the volume of the left maxillary sinus could be used as an indicator in determining the sex of an unknown individual and recorded several observations to draw any meaningful conclusion. Based on these observations, it was concluded that the volume of left maxillary sinus in males and females show a large degree of difference and can be used as an indicator in determining the sex of an unknown individual. The present study reported mean value of the volume of left maxillary sinus in males to be 14.54 ± 2.18cm^3 and in females, it was reported to be 9.88 ± 1.80 cm^3. The difference in mean value of volume between males and females was found to be more than 50% of the volume of the female left maxillary sinus. (Table 2)

Several studies have been performed in recent years to that concluded that the volume of the left maxillary sinus could be used to determine the sex of an unknown individual. One such study by **Nadia Araneda et al.,(2019)** [69] reported mean value of volume in males to be 19.69 ± 7.39cm^3 and in females, it was reported to be 12.28 ± 3.69 cm^3 which was statistically significant. This study also found male volume of left maxillary sinus was larger than the volume of the left maxillary sinus in females by over 50% of the volume of the left maxillary sinus in females. A similar study was performed by **Suwarna Dangore Khasbage et al., (2018)** [61] which stated that the mean value of the left maxillary sinus volume in males was 16.46 ± 6.39 cm^3 and in females it was reported to be 10.77 ± 5.03 cm^3. This study also concluded that difference between the volume was large enough to be used as an indicator in determining the sex of an unknown individual. The study by Mukul Prabhat et al., (2016) drew similar conclusions and reported mean value in males to be 15.19 ± 3.94 cm^3 and in females, it was reported to be 10.95 ± 4.98cm3 which was found to be statistically significant. The study by **Sanda Usharani et al., (2017)** [64] provided further evidence for the findings of the present study and drew the same conclusion as the present study. This study reported mean value in males to be 33.91 ± 2.15 cm^3 and in females, it was reported to be 22.70 ± 1.42 cm^3. Even though this study was performed on a different demography of people, and thus found a much larger mean volume of the left maxillary sinus in both males and females, the difference in volume between males and females was still consistent with the findings of the present study. Similarly, the study by **Ranjeeth kumar Kanthem, (2015)** [11] was also performed on a different demographic and reported larger mean volume in both males and females, however, the difference in volume was again consistent with the findings of the present study. This study reported mean value of volume of left maxillary sinus in males to be 37.64 ± 38.71 cm^3 and in females, it was reported to be 21.10 ± 20.11 cm^3.

There have also been a few studies that failed to find any significant difference in the volume of left maxillary sinus between males and females. One such study by **Balaji Babu Bangi et al.,** [57] **(2017)** reported mean value of volume in males to be 13.35 ± 6.10 cm^3 and in females, it was reported to be 12.77 ± 5.44 cm^3. **Ayeesha Urooge et al., (2017)** [59] also performed a study in 2017 and found negligible difference in the volume of left maxillary sinus between males and females. This study stated that the mean volume in males was 16.58 ± 5.69 cm^3 and in females, it was reported to be 16.59 ± 5.09 cm^3 which was statistically insignificant as the p value was found to be 0.99.

7. SUMMARY AND CONCLUSION

In the adult skeleton gender prediction is the first step of the identification process as subsequent methods for age and stature estimation are gender dependent. The accuracy of gender determination depends on the completeness of the remains and the degree of sexual dimorphism inherent in the population. In cases of mass disasters, like airplane crashes, terrorist attacks, landslides, explosions and warfare even the skull and other bones are badly blemished, however it has been documented that maxillary sinus remain intact.

Hence this study was aimed at documenting the accuracy of morphometric evaluation of maxillary sinus using 3D CT for gender determination. In this study, a total of 60 CT images (30 males and 30 females) were included. Different parameters of maxillary sinus were estimated for gender determination. The parameters include the maximum Superoinferior dimension of right and left maxillary sinus in coronal multiplanar reformatted [MPR] image, maximum medio-lateral dimension of right and left maxillary sinus in coronal MPR image, maximum antero-posterior dimension of right and left maxillary sinus in axial MPR image, volume of right and left maxillary sinus using “Region Growing” function of SYNGO CT VA48A software on Siemens 128 slice CT scan console from 3D image.

In the present study, the mean value of superoinferior, medio-lateral, antero-posterior dimension and volume of maxillary sinus of right side of female was comparatively lower than male. Between two groups (male and female) on comparing the mean value of superoinferior, medio-lateral, antero-posterior dimension and volume of maxillary sinus of right side, statistically significant results were found which was found to be lower by 12.57, 15.73, 9.33 and 33.17% respectively in female as compared to male. The mean maxillary sinus dimension at left side was also comparatively lower in female than male. Subsequently, the mean value of superoinferior, medio-lateral, antero-posterior dimension and volume of left maxillary sinus between two groups (male and female). These dimensions were recorded to be lowered by 10.29, 17.81, 8.18 and 32.05% respectively in female as compared to male which was statistically significant.

Hence, determination of gender by measuring Supero-inferior, medio-lateral, antero-posterior dimension and volume of the maxillary sinus on 3DCT showed statistically significant results. These parameters can be used for gender prediction with a fair degree of accuracy when the whole skeleton is not available. Hence the study concludes that morphometric evaluation of maxillary sinus using 3D CT Reconstruction is a helpful diagnostic parameter in gender determination of a cranium of unknown origin. However, further studies with larger sample size are required to make this procedure conclusive and achieve standardization.

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DISSERTATION PROFORMA

MORPHOMETRIC EVALUATION OF MAXILLARY SINUS AS A TOOL FOR GENDER DETERMINATION : 3D COMPUTED TOMOGRAPHY RECONSTRUCTION STUDY IN LUCKNOW POPULATION

DEPARTMENT OF ORAL MEDICINE & RADIOLOGY

Babu Banarasi Das College of Dental Sciences, Lucknow (U.P.)

OPD NO: Case No:

Name: Age: Sex:

Radiographic Investigations (3 D COMPUTED TOMOGRAPHY):

MAXILLARY SINUS LINEAR MEASUREMENTS

1. **RIGHT SIDE**

IMAGE	PARAMETER	MEASUREMENT (mm)
Coronal	Superoinferior	
Coronal	Mediolateral	
Axial	Anteroposterior	

2. **LEFT SIDE**

IMAGE	**PARAMETER**	**MEASUREMENT (mm)**
Coronal	Superoinferior	
Coronal	Mediolateral	
Axial	Anteroposterior	

MAXILLARY SINUS VOLUMETRIC MEASUREMENTS (cm^3)

Right side:

Left side:

STUDENT SIGNATURE GUIDE SIGNATURE

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES (FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

The project titled **"Morphometric Evaluation of Maxillary Sinus as a Tool for Gender Determination: 3D Computed Tomography Reconstruction Study in Lucknow Population."** submitted by **Dr Sneha Agrawal** Post graduate student from the **Department of Oral Medicine & Radiology** as part of MDS Curriculum for the academic year 2018-2021 with the accompanying proforma was reviewed by the Institutional Research Committee present on **27th November 2018** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

Prof. Vandana A Pant
Co-Chairperson

Prof. B. Rajkumar
Chairperson

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the VII^th^ Institutional Ethics Sub-Committee

IEC Code: 09 **BBDCODS/01/2019**

Title of the Project: Morphometric Evaluation of Maxillary Sinus as a Tool for Gender Determination: 3D Computed Tomography Reconstruction Study in Lucknow Population.

Principal Investigator: Dr. Sneha Agrawal **Department:** Oral Medicine & Radiology

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: New, MDS Project Protocol

Dear Dr. Sneha Agrawal,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 10th January 2019.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics & Dentofacial Orthopedics, BBDCODS, Lucknow
4.	Dr. Sumalatha M.N. Member	Reader, Department of Oral Medicine & Radiology, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala
21/01/19

(Dr. Lakshmi Bala)
Member-Secretary
IEC

Member-Secretary
Institutional Ethic Committee
BBD College of Dental Sciences
BBD University
Faizabad Road, Lucknow-226028

(Dr. B. Rajkumar)
Principal
BBDCODS

PRINCIPAL
Babu Banarasi Das College of Dental Sciences
(Babu Banarasi Das University)
BBD City, Faizabad Road, Lucknow-

MASTER CHART

Group 1: Male

SNO.	OPD NO.	NAME	Age (yrs)	RIGHT MAXILLARY SINUS DIMENSION				LEFT MAXILLARY SINUS DIMENSION			
				Supero-Inferior (mm)	Medio-Lateral (mm)	Antero-Posterior (mm)	Volume (cm^3)	Supero-Inferior (mm)	Medio-Lateral (mm)	Antero-Posterior (mm)	Volume (cm^3)
1	1388/18	ABDUL HAQUE	60	38.00	31.60	38.60	15.45	36.30	32.60	40.60	16.02
2	1392/18	MUSTAQ AHAMAD	35	37.70	23.60	37.00	10.97	37.00	24.50	37.10	11.21
3	1390/18	RAM TRIPATHI	54	44.30	29.60	38.80	16.96	45.10	35.70	39.90	21.41
4	CT10733	NEERAJ	22	39.50	33.40	35.20	15.48	32.50	35.00	36.20	13.73
5	CT09009	DEERAJ	26	36.00	32.60	38.10	14.90	33.20	28.10	38.00	11.82
6	CT07285	SUBHAM	30	40.56	31.79	39.56	17.00	38.10	32.90	42.36	17.70
7	CT05561	SANDEEP	36	42.36	28.65	41.33	16.72	39.56	25.65	41.25	13.95
8	CT03837	ANIL	35	35.69	25.36	40.36	12.18	41.33	26.36	40.36	14.66
9	CT02113	ANOOP	39	40.36	26.35	42.09	14.92	40.36	27.36	39.65	14.59
10	CT00389	ANKUR	22	40.23	28.54	44.36	16.98	40.61	24.36	38.52	12.70
11	CT01335	GORAKH	26	39.65	24.86	37.35	12.27	36.25	28.36	39.36	13.49
12	CT03059	NARENDR	28	36.60	29.36	40.03	14.34	33.56	31.25	38.00	13.28
13	CT04783	LAKHVEER	26	40.36	28.85	41.25	16.01	35.65	28.65	42.36	14.42
14	CT06507	JAKISHAN	38	36.25	24.78	40.36	12.08	34.85	29.96	41.25	14.36
15	CT08231	SALEEM	40	40.65	25.35	39.65	13.62	39.41	28.69	43.24	16.30
16	CT09955	SALMAN	56	38.36	31.25	40.61	16.23	36.32	30.90	40.60	15.19

17	CT11679	LAVKUSH	52	43.90	27.65	39.26	15.89	41.33	25.65	37.10	13.11
18	CT13403	RAMPRAVESH	43	38.36	25.36	41.02	13.30	33.56	26.36	39.90	11.77
19	CT15127	MANGEET	58	40.36	24.36	40.32	13.21	38.65	27.36	38.00	13.39
20	CT16851	ALOK	57	39.56	23.88	36.02	11.34	33.20	24.36	42.36	11.42
21	CT18575	PRADEEP	52	36.56	30.65	44.58	16.65	38.10	30.36	41.25	15.90
22	CT20299	KULDEEP	24	40.30	29.60	40.03	15.92	39.56	27.36	40.36	14.56
23	CT22023	SURAJ	26	36.00	29.35	41.25	14.53	41.33	24.36	40.60	13.63
24	CT23747	ASHUTOSH	54	38.44	32.60	40.03	16.72	40.36	30.36	43.09	17.60
25	CT25471	ASHOK	58	40.36	30.56	41.25	16.96	40.58	31.25	39.90	16.87
26	CT27195	RAVI	48	36.25	32.60	39.96	15.74	40.15	28.65	43.03	16.50
27	CT28919	VINAY	34	42.36	31.79	40.04	17.97	38.56	29.96	40.60	15.63
28	CT30643	MANSARAM	22	38.36	30.65	38.61	15.13	34.85	28.69	43.26	14.42
29	CT32367	SARAFAT ALI	25	43.90	25.36	42.21	15.66	40.36	26.90	39.90	14.44
30	CT34091	AMIT	28	35.26	24.36	39.36	11.27	33.54	25.02	43.02	12.03

Group 2: Female

SNO.	OPD NO.	NAME	Age (yrs)	Right MAXILLARY SINUS DIMENSION				LEFT MAXILLARY SINUS DIMENSION			
				Supero-Inferior (mm)	Medio-Lateral (mm)	Antero-Posterior (mm)	Volume (cm^3)	Supero-Inferior (mm)	Medio-Lateral (mm)	Antero-Posterior (mm)	Volume (cm^3)
1	CT09341	KOMAL	35	38.8	26.0	38.62	12.99	33.10	28.00	39.10	12.08
2	2485435	MEERA	25	34.9	23.9	39.31	10.93	36.70	22.20	39.00	10.59
3	CT09348	SALU	26	32.77	18.37	40.01	8.03	29.91	18.26	35.69	6.50
4	CT09050	PRATIMA	28	33.58	24.51	31.98	8.77	36.94	29.56	36.25	13.19
5	CT08752	VANDNA	30	36.98	25.35	32.65	10.20	35.58	28.36	38.25	12.87
6	CT08454	SAVITA	36	30.12	26.58	33.58	8.96	32.99	29.35	39.65	12.80
7	CT08156	SARITA	35	35.98	24.35	36.59	10.69	36.25	22.25	38.74	10.42
8	CT07858	VNEETA	39	36.54	21.54	35.69	9.36	33.22	20.36	35.68	8.04
9	CT07560	AFSANA	32	39.01	25.56	39.35	13.08	37.56	22.58	37.26	10.53
10	CT07262	RADHIKA	28	38.01	26.42	40.01	13.39	35.63	22.25	36.56	9.66
11	CT06964	NEETU	26	36.54	20.54	31.98	8.00	38.65	22.35	34.54	9.95
12	CT06666	VIJAY LAXMI	35	36.84	21.36	32.65	8.56	37.85	18.32	34.69	8.02
13	CT06368	LAXMI	36	37.85	27.56	36.02	12.52	39.01	27.89	34.88	12.65
14	CT06070	TAHSEEN	39	31.45	26.36	32.65	9.02	30.35	24.35	34.99	8.62
15	CT05772	PRATIBHA	40	36.35	24.56	33.58	9.99	33.70	22.25	36.05	9.01
16	CT05474	ANUSKA	40	36.01	23.25	36.59	10.21	34.91	23.36	37.45	10.18

17	CT05176	RESHAM	50	32.32	21.58	35.69	8.30	30.68	22.25	38.25	8.70
18	CT04878	RASMI	54	31.01	23.56	39.36	9.59	30.91	25.36	39.02	10.20
19	CT04580	DIVYA	56	30.02	22.54	35.69	8.05	29.94	24.35	35.68	8.67
20	CT04282	SWATI	52	29.54	23.56	39.39	9.14	30.56	21.25	37.26	8.07
21	CT03984	DIKSHA	26	31.84	24.54	40.01	10.42	32.99	22.36	36.56	8.99
22	CT03686	SHIVANI	36	29.85	23.36	31.98	7.43	28.99	22.58	34.54	7.54
23	CT03388	POOJA	35	32.01	24.25	38.62	9.99	33.25	22.00	39.10	9.53
24	CT03090	RUCHI	27	28.02	25.25	39.31	9.27	30.22	23.20	39.02	9.12
25	CT02792	SUMAN	29	37.85	22.56	40.01	11.39	33.56	20.26	35.69	8.09
26	CT02494	RAJMANI	26	31.45	20.61	39.05	8.44	34.25	21.36	36.25	8.84
27	CT02196	VIDYAWATI	24	35.35	25.54	32.65	9.83	32.02	24.36	35.69	9.28
28	CT01898	JAGRANI	35	34.26	24.56	33.58	9.42	33.56	23.35	36.25	9.47
29	CT01600	CHANDRAWATI	36	36.32	25.59	36.59	11.34	35.63	24.36	40.25	11.64
30	CT01302	GEETA	38	37.12	26.58	33.58	11.04	38.65	25.65	39.65	13.10

Statistical Analysis

Arithmetic Mean

The most widely used measure of central tendency is arithmetic mean, usually referred to simply as the mean, calculated as

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Standard deviation and standard error

The standard deviation (SD) is the positive square root of the variance, and calculated as

$$SD = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

where, n= no. of observations. The and SE (standard error of the mean) is calculated as

$$SE = \frac{SD}{\sqrt{n}}$$

Minimum and Maximum

Minimum and maximum are the minimum and maximum values respectively in the measure data and range may be dented as below

Range = Min to Max

and also evaluated by subtracting minimum value from maximum value as below

Range = Maximum value-Minimum value

Median

The median is generally defined as the middle measurement in an ordered set of data. That is, there are just as many observations larger than the median as there are smaller. The median (M) of a sample of data may be found by third arranging the measurements in order of magnitude (preferably ascending). For even and odd number of measurements, the median is evaluated as

M= [(n+1)/2]th observation- odd number

M= [n(n+1)/2]th observation – even number

Student's t Test

Student's t-test was used to calculate the differences between the means of two groups

$$t = \frac{\bar{X}_1 - \bar{X}_2}{SE}$$

where,

$$SE = \sqrt{S^2 \times \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}$$

S^2 is the pooled variance and n_1 and n_2 are number of observations in group 1 and 2 respectively. The degrees of freedom (DF) is calculated as

$$DF = n1 + n2 - 2$$

Simple Linear Correlation

The relative association between two variables (X and Y) was calculated according to Karl Pearson correlation coefficient (r) method. The correlation coefficient also called as "simple correlation coefficient" is calculated as

$$r = \frac{\Sigma\, xy}{\sqrt{(\Sigma\, x^2\ \Sigma\, y^2)}}$$

or,

$$r = \frac{\Sigma\, XY - \dfrac{\Sigma X\ \Sigma Y}{n}}{\sqrt{\left(\Sigma X^2 - \dfrac{(\Sigma X)^2}{n}\right)\left(\Sigma Y^2 - \dfrac{(\Sigma Y)^2}{n}\right)}}$$

The value of r should be either positive, zero or negative; should be ranged from -1 to +1 and has no units of measurement. A positive correlation implies that for an increase in the value of one of the variables, the other variable also increases in value; a negative correlation indicates that an increase in value of one of the variables is accompanied by a decrease in value of the other variable and zero correlation indicates that there is no linear association between the magnitudes of the two variables; that is, a change in magnitude of one does not imply a change in magnitude of the other.

Statistical significance

Level of significance "*P*" is the probability signifies level of significance. The mentioned P in the text indicates the following:

$P > 0.05$ - not significant (ns)

$P < 0.05$ - just significant (*)

$P < 0.01$ - moderate significant (**)

$P < 0.001$ - highly significant (***)

URKUND

Urkund Analysis Result

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Significance: 9 %

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