“DETERMINATION OF SEX FROM HYOID BONE”

Dissertation submitted in partial fulfilment of the requirements for the degree

M.D. (Forensic Medicine)

BRANCH- XIV

INSTITUTE OF FORENSIC MEDICINE
MADRAS MEDICAL COLLEGE
CHENNAI–600003

THE TAMILNADU
Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

2016-2019

BONAFIDE CERTIFICATE

This is to certify that the work embodied in this dissertation entitled **"DETERMINATION OF SEX FROM HYOID BONE "** has been carried out by **Dr.A.H.SUGANCHANDER,** Post Graduate student under my supervision and guidance for his study leading to Branch XIV M. D. Degree in Forensic Medicine during the period of May - 2016 to May - 2019.

Prof. Dr.R. Jayanthi M.D.,FRCP.,
Dean
Madras Medical College &
Rajiv Gandhi Govt. General Hospital,
Chennai-3.

Prof.Dr.P.Parasakthi M.D.,
Director and Professor
Institute of Forensic Medicine,
Madras Medical College,
Chennai-3.

Date:
Place:

DECLARATION

I, **Dr.A.H.SUGANCHANDER,** solemnly declare that this dissertation entitled **"DETERMINATION OF SEX FROM HYOID BONE**" is the bonafide work done by me under the expert guidance and supervision of **Dr.P.PARASAKTHI, M.D.,** Professor and Director, Institute of Forensic Medicine, Madras Medical College, Chennai–3.This dissertation is submitted to the Tamil Nadu Dr.M.G.R Medical University towards partial fulfilment of requirement for the award of M.D., Degree (Branch XIV) in Forensic Medicine.

Dr.A.H.SUGANCHANDER

Place:
Date:

INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI 600 003

EC Reg.No.ECR/270/Inst./TN/2013
Telephone No.044 25305301
Fax: 011 25363970

CERTIFICATE OF APPROVAL

To
Dr.A.H.Suganchander
I Year PG in MD Forensic Medicine
Institute of Forensic Medicine
Madras Medical College
Chennai 600 003

Dear Dr.A.H.Suganchander,

The Institutional Ethics Committee has considered your request and approved your study titled **"DETERMINATION OF SEX FROM HYOID BONE" - NO.11032017(I)**.

The following members of Ethics Committee were present in the meeting hold on **02.03.2017** conducted at Madras Medical College, Chennai 3

1.Dr.C.Rajendran, MD.,	:Chairperson
2.Dr. K.Narayanasamy,MD,DM.,Dean(FAC), MMC,Ch-3	:Deputy Chairperson
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10.Tmt.Arnold Saulina, MA.,MSW.,	:Social Scientist

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

Member Secretary - Ethics Committee

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003

ACKNOWLEDGEMENT

I am greatly obliged to the Dean, **Dr.R.JAYANTHI M.D., FRCP.,** Madras Medical College and Rajiv Gandhi Govt. General hospital, Chennai-3 for allowing me to complete this study.

I would like to express my heart felt gratitude to my esteemed **Professor & Director**, **Dr.P.Parasakthi M.D.,** who has been a constant source of inspiration and encouragement.

I am especially thankful to my former Professor & Director, **Dr.V.Murugesan M.D.**, **D.A., F.C.C.P., Associate Professor, Dr.T.Vedanayagam M.D.,** for their valuable guidance in conducting the study and Assistant Professors, **Dr.S.Ramalingam M.D., Dr.R.Narendar M.D., Dr.M.Guhan M.D., Dr.T.Ezhilkothai M.D., Dr.S.Sylvia M.D**., Institute of Forensic Medicine, Madras Medical College, Chennai-3 for their interest and encouragement, in bringing out this dissertation for my MD exam.

I thank all my Colleagues and my fellow post graduates for their immense support and help.

Above all, I thank god almighty, for blessing me to do this dissertation.

DEDICATION

To my

Father, A.K.Hemachandran,

Mother, A.H.Amsaveni

&

my wife, Dr.M.Jayanthi Gayathri MBBS,

for their immense support and affection

INDEX

ABBREVIATIONS

A.M.	-	Arithmetic Mean
M.D.	-	Mean Deviation
LT	-	Left
RT	-	Right
ANOV	-	Analysis of Variance
BOX's M	-	BOX's Test for Equivalence of Covariance Matrices
S.D	-	Standard Deviation

CERTIFICATE – II

This is to certify that this dissertation work titled **"DETERMINATION OF SEX FROM HYOID BONE"**of the candidate **Dr.A.H.SUGANCHANDER** with registration Number **201624003** for the award of **M.D** in the branch of **FORENSIC MEDICINE**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows 6% of plagiarism in the dissertation.

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INTRODUCTION

Determination of sex is the first and foremost step in the process of identifying human remains in forensic casework. Identifying the unknown remains is a challenging and crucial task in the field of forensic medicine. In Cases such as major accidents, completely burnt bodies, mutilated bodies, decapitated bodies and in buried bodies, sex and age of the victims should be determined for the purpose of identification. For this purpose, bones are sent for examination to determine age and sex of the body. Identification becomes easy for the forensic experts, if whole skeleton is available for examination. According to **krogman**(1), When both pelvis and skull are available accurate results may be obtained in 98% of the cases. Pelvis alone gives 95% accurate results, skull alone gives 92% accurate results and long bones give 80-85% results. But most experts do not claim 100% accuracy even when entire skeleton is available. Apart from bones such as pelvis, skull, mandible, sternum, manubrium and femur (2, 3) which usually help in identification of the sex, other bones such as scapula, tibia, vertebra, ribs and hyoid can also tell about the sex of the body.

Sex determination(4) from skeletal remains is a well studied and extensively documented subject. The hyoid bone too has its own uses and application in these types of studies

Hyoid bone is a solitary bone that has no bony articulations(5) but provides attachment for muscles, ligaments, and fascia of the pharynx,

mandible, and cranium. Though hyoid bone exhibit sexual dimorphism and morphometric variables, it has drawn less attention in studies of this nature. Sex determination (4) becomes challenging to forensic experts when the bodies are badly mutilated or in advance state of decomposition or even at times skeletonised. Sometimes only neck structures(6,7) may be available for examination and further investigation. In such cases hyoid bone which can easily be secured for examination, forms a vital key in determination of sex (4).

Hyoid bones can also be used in identification of victims in mass disasters, where identification of dead bodies is a difficult task. International authors have published many articles about sex determination from skeletal remains but, there are only few documented Indian articles exist till today about these studies.

The shape of hyoid bone may influence its susceptibility to fracture and hyoid bone fractures are frequently confused with normal variation in both clinical and forensic settings. Although the relationship between hyoid bone shape and fracture pattern figures prominently in criminal investigations of strangulation cases, the morphological variations of sex(13) and age in the hyoid bone are yet to gain popularity in the forensic field.

There are many osteometric measurements which can be used in the determination of sex of the hyoid bone. Hence, the present study was conducted to distinguish between male and female hyoid bones using fewer and reliable osteometric measurements.

REVIEW OF LITERATURE

Identification is the process of fixation of the personality of an individual based on certain physical characteristics. The identification may be either partial or complete. In partial identification, only certain details about the person or body are found. Many details which remain unknown in partial identification may be later revealed by the police during the process of investigation. Whereas, in complete identification, all the details are revealed and the individuality of the person or the body is fixed. Identification is essential in both living and dead persons. Establishing the identity of the dead body is an important part of Corpus Delicti.

Accurate identification of the dead body and the proof of corpus delicti are necessary before a sentence is passed in homicidal cases. There are cases noted where unknown dead bodies, decomposed bodies and remains of bones are brought to the forensic expert to produce false charge against a person for committing homicide. The three most important datas used in identification are Age, Sex and Stature.

The identification becomes challenging in cases of mass disasters, bomb blast, fire accidents, terrorist activities, mutilated bodies, decomposed bodies and skeletal remains. Identification of the living person is usually investigated by the police officers. In the identification of the dead bodies, the doctor has a greater role to play.

Factors useful to determine the sex in living persons

Determination of sex plays an important role in establishing the identity of an individual. It is important to determine sex in cases of marriage, impotence, divorce, legal heir ship and rape. Sex of a living person can be determined from:

I) Physical morphology

II) Sex chromatin

III) Gonadal biopsy

IV) Hormonal Assay

V) DNA Sampling

VI) Examination of X-Rays

VII) Metric analysis

Physical morphology- Sex of an individual can be easily determined from external examination of an individual. Various external features are taken in to consideration to differentiate between male and female sex**:**

I) Genitals

II) Build

III) Shoulders

IV) Waist

V) Trunk

VI) Thorax

VII) Limbs

VIII) Arms

IX) Thighs

X) Gluteal region

XI) Wrist and ankles

XII) Breasts

XIII) Pubic hair

XIV) Body hair

XV) Head hair

XVI) larynx

Sex chromatin – Out of 46 chromosomes present in each cell of our body, 44 chromosomes are known as autosomes and remaining 2 chromosomes are known as sex chromosomes. These sex chromosomes are XY in males and XX in females. In 1949, Barr and Bertram noticed a nodule in the nuclei of the cells of a female cat. Later, they noticed the similar nodule in the cells of all normal women in varying degree of percentage.

Microscopically, this nodule is seen as a condensed Plano convex mass lying near nuclear membrane inside the nucleus of the cell. This is known as the **sex chromatin** or **Barr body**. They are demonstrated in the cells of buccal mucosa, skin and cartilages. In the cells of buccal mucosa, the percentage of nuclei containing chromatin body ranges from 20-80% in females and 0-4% in males.

Davidson body-They are small nuclear lobes, resembling drumstick present in the neutrophils of the female sex**.** To determine female sex, Davidson's bodies must be present up to six percent in the neutrophils of the peripheral smear. They are absent in males

Karyotyping- In this method, the human chromosomes are studied in detail based on their morphological properties and patterns.

Gonadal Biopsy- Sex of an individual can be confirmed by taking biopsy from the primary gonadal structures. The primary gonadal structures are testis in male and ovaries in female. The histology of the gonadal structures are identified using microscope.

Hormonal Assay- Sex of an individual can be determined by measuring the levels of steroidal sex hormones such as testosterone and estrogen in the blood levels. The ovaries secretes larger amount of estrogen and testis secretes larger amount of testosterone. However, it is not a reliable method for identification.

DNA Analysis- From the analysis of DNA in the blood or blood stains, sex of the person can be made out accurately.

Examinations of X-Rays- There are two different methods used for sex determination using X-Rays

I) **Rao and Pai's classification-** It is based on the calcification pattern of the costal cartilages seen in the X-rays. It is helpful in determining the sex in the age group of 16- 20 years. Three patterns of costal cartilage calcification are noted in the X-rays. They are:

- Square bracket type – males
- Linear type- males
- Central tongue shaped- males

II) **Mandibular canine index** can also be used to determine the sex of a person using X-Rays

Metric System- Various measurements, dimensions and ratios are obtained from the footprints and they are analysed for the purpose of identification of an individual.

Sex determination in the decomposed body- First, the level of decomposition is assessed and identification of primary sex organs and gonads such as uterus, ovaries , fallopian tubes and cervix in females, and prostate, testis and penis in males has been made. In advanced decomposed dead bodies, sex can be determined by identifying uterus or prostate which resists putrefaction for long time. When the primary sex organs are not identifiable, examination of skeletal remains for the sexual characters is a useful tool in sex determination.

Sex determination in the Skeletal Remains-For a trained forensic expert, it seldom poses a problem to determine sex from the skeletal remains. The chances of estimating sex from skeletal remains depend upon the number of bones available for identification. More the number of bones available, higher the accuracy level attained. Bones such as **Skull, Pelvis, mandible and Long bones** are widely used for identification.

Pelvis- Sexual differences usually do not appear in the bones until puberty except pelvis. The pelvis is the best suited bone for sex determination before puberty, since pelvic bones in females are designed for delivery of a baby.

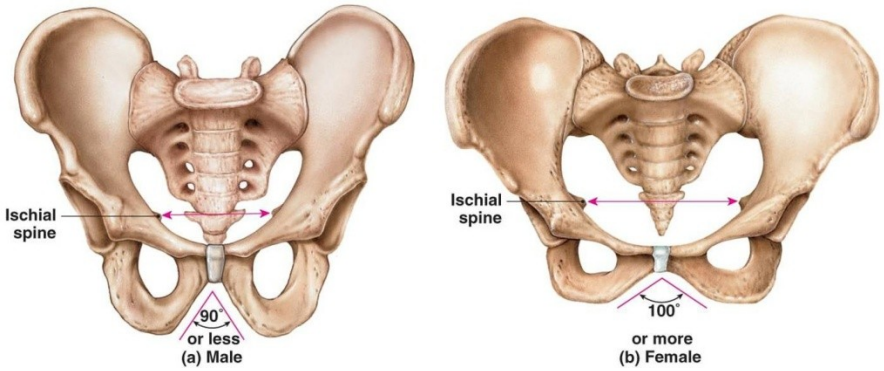


Fig:1-Difference between male and female pelvis

In the pelvic bone(3,5,12), sexual features are independent of each other and even one finding may contradict the other in the same bone(3,5). Usually, the male pelvis is massive, harder and rougher than the female pelvis. The male pelvis stands higher and erect than the female counterpart. The greater sciatic notch, sub pubic angle, pelvic inlet and pelvic outlet are more in females than in males. The sub pubic angle is 90 degrees or less in males, whereas it is

obtuse or more than 100 degrees in females. The ischial tuberosity(5) is inverted in males, whereas everted in females. The sex of a female child is determined ideally from the greater sciatic notch of the pelvic bone. The Pre-auricular sulcus (characteristic of female pelvis) will be broad, deep and frequently seen in female pelvis. chilotic line is an anthropometric line in pelvis, used to determine sex. The accuracy of pelvic bone alone is 95% in determination of sex.

Skull- Sex differences noted in the morphology of skull(3,5,12) are quite reliable with 90% accuracy. The male skull is larger, heavier, rugged and more capacious than the female skull. The features such as glabella, supraorbital ridges, zygomatic arch and occipital protuberance are more prominent in males than females. The parietal and frontal eminence are less prominent in males than in females. The mastoid process is large, round and blunt in males, whereas it is small, smooth and pointed in females. The digastric groove is deep in males, whereas narrow in females. In males, the Orbits are square in shape, small and have rounded margins. Females tend to have round and large orbits with sharp edges.

Long bones- The sex of the long bones can be determined on the basis of the medullary index. The sex differentiating features are identifiable only on the ends of the long bones and are used only when the whole intact long bone is available. When a fragment of bone or only the shaft is available, then the medullary index is useful in determining the sex. The long bones alone gives accuracy of 80% in determining the sex of an individual

In this part, the detailed anatomy of the hyoid bone, the functions of the hyoid bone, the significance of hyoid bone from the forensic aspect, and various studies on sex determination using hyoid bone are elaborated in detail.

I. ANATOMY OF THE HYOID BONE(3,5,12,30)

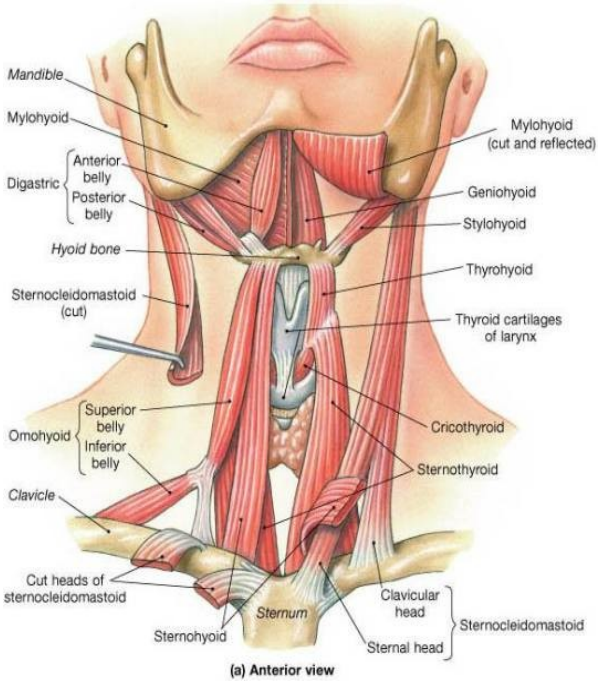


Fig: II- Hyoid bone in the neck

Hyoid bone is the U-shaped bone located in the front of midline of neck just above the larynx and below the mandible. It lies opposite the upper part of the 4th cervical vertebra and about 2 cm below the level of the lower margin of the mandible when the head is at rest. It is suspended from styloid process of the temporal bone by the styloid ligaments(30). It is the only bone in the body that articulates with no other bones. Hyoid bone provides muscular attachments to the muscles, that forms the floor of the mouth and to the tongue above, to the larynx below, and to the epiglottis and pharynx posteriorly

The hyoid bone has following parts:

A) The body

B) Two Greater cornua or horns

C) Two Lesser cornua or horns

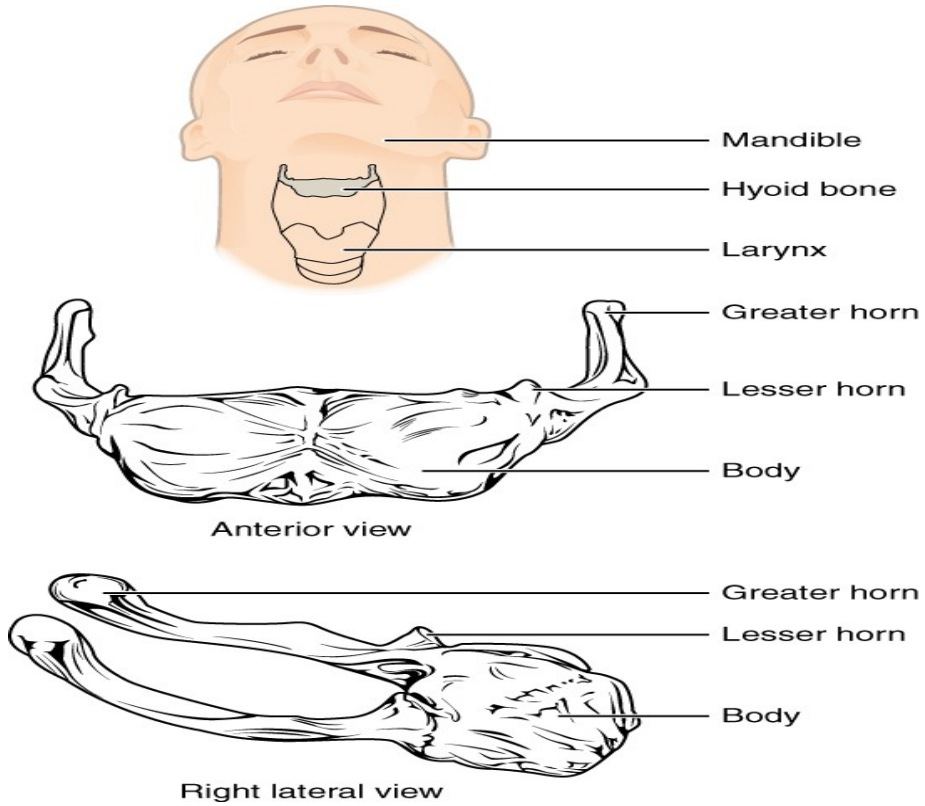


Fig: III- Parts of the Hyoid Bone

Body – The body is the central most part of the hyoid bone. The body of the hyoid bone has two surfaces namely:

I) The anterior surface

II) The posterior surface

The body of the hyoid bone has two borders :

I) The upper border

II) The lower border

At the front, the body is convex and it is directed upwards and forwards. It is crossed by a transverse ridge with a slight convexity downwards, and in many cases a vertical median ridge divides it into two lateral halves. The portion of the vertical ridge above the transverse line is present in majority of specimens, but below the transverse line it is rarely seen. The posterior surface is concave and it is directed backward and downwards, and both the thyrohyoid membrane and loose areolar tissue separates it from the epiglottis. A bursa intervenes between the hyoid bone and the thyrohyoid membrane(29,30). The upper and lower borders of the hyoid bones gives various muscular attachments

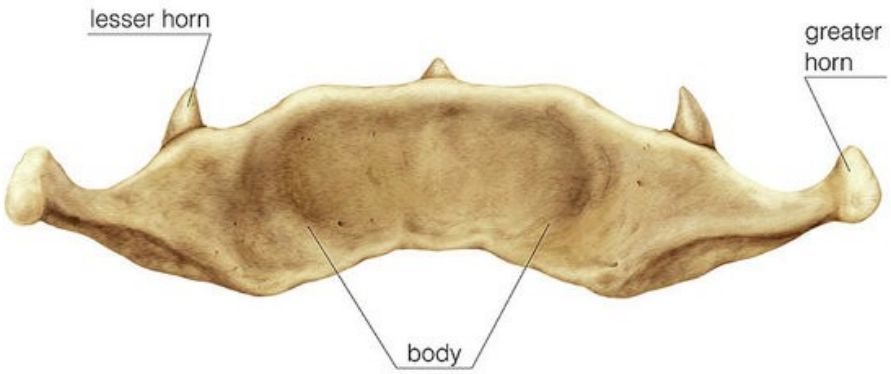


Fig: III- Body of the hyoid bone: Posterior view

Greater Cornua- The greater horns(30) project backwards from the lateral ends of the body of the hyoid bone. They are horizontally flattened, taper posteriorly , and each ends in a tubercle(30).

The greater cornua of the hyoid bone has got two surfaces:

I) The Anterior Surface

II) The Posterior Surface

It has two borders namely,

I) The Medial Border

II) The Lateral Border

In early life, the greater cornua are connected to the body by cartilage, but after middle age they are united by bony fusion. When the throat is gripped between finger and thumb above the level of thyroid cartilage, the greater horn can be felt and can be moved from side to side.

Lesser Cornua- The lesser horns are the two small conical projections at the junction between the body and the greater horns of the hyoid bone. They are connected to the body by fibrous tissue and occasionally to the greater horns by diarthrodial joints, which usually persist throughout life but later may get ankylosed. The lesser horns are situated in the line of transverse ridge on the body and appear to be continuation of it.

MUSCLE ATTACHMENTS ON THE HYOID BONE

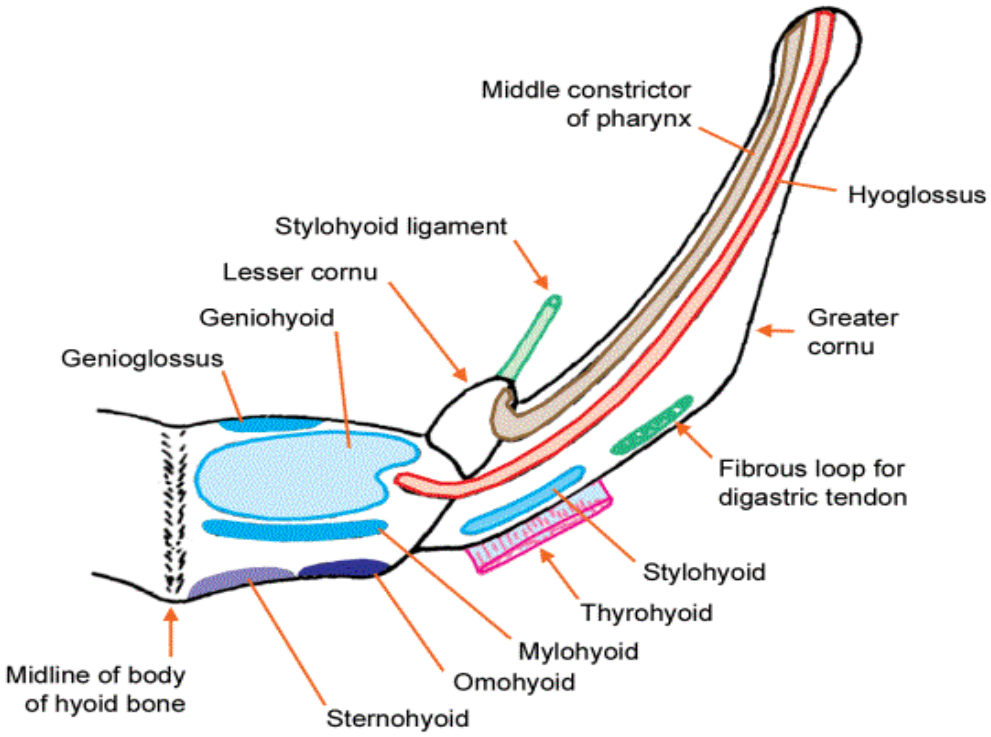


Fig: IV- Attachments on the hyoid bone

The hyoid bone serves as a fulcrum for the muscles involved in the process of swallowing. During the process of swallowing(3), the suprahyoid muscles elevate the hyoid bone when the mandible is fixed. Various muscular attachments(2,3,5) of the hyoid bone are briefly discussed below

- The anterior surface of the body of the hyoid bone provides insertion to the geniohyoid and mylohyoid muscles and gives origin to a part of the hyoglossus muscle which extends to the greater cornua of the hyoid bone.
- The upper border of the body provides insertion to the fibres of the genioglossi and gives attachment to the thyrohyoid membrane.

- The lower border of the body gives attachment to the pretracheal fascia. In front of the pretracheal fascia, the sternohyoid muscle is inserted medially and laterally by the superior belly of omohyoid.
- Below the omohyoid muscle, there is an attachment of the thyrohyoid muscle that extends to the lower border of the greater cornua.
- The medial border of the greater cornua provides attachment to the muscles such as the stylohyoid muscle, digastrics pulley and the thyrohyoid membrane(3,5).
- The lateral border of the greater cornua provides insertion to the thyrohyoid muscle anteriorly . The investing fascia is attached throughout the length of the lateral border
- At the tip of the lesser cornua, the stylohyoid ligament is attached. From the posteriolateral aspect of the lesser cornua, the middle constrictor muscle is attached

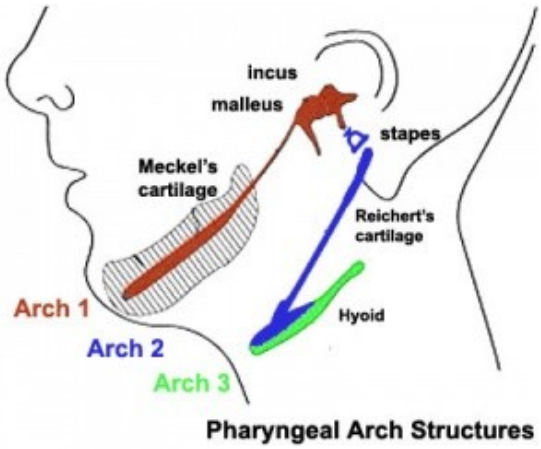
DEVELOPMENT OF THE HYOID BONE

The upper part of the body and lesser cornua develop from **second branchial arch**, while the lower part of the body and greater cornua develop from the **third branchial arch(14-16)**

Second Arch or Hyoid Arch- The cartilaginous bar of this arch is known as the Reichert's cartilage, which extends dorsally up to the cartilaginous ear capsule. The dorsal part of the cartilage is ossified to form the stapes of the middle ear. The succeeding part forms the styloid process of the temporal bone and the stylo-hyoid ligament. The ventral part of the cartilage is converted into the lesser cornu and the upper part of the body of the hyoid bone

Third Arch- The dorsal part of this arch disappears, and the ventral part is ossified to form the greater cornu and lower part of the body of hyoid bone. However, frazer considers that the hyoid bone is entirely derived from the third arch and establishes the secondary connection with the second arch

Fig: V- Development of the hyoid bone



OSSIFICATION OF THE HYOID BONE

The hyoid bone is ossified from six ossification centres(14,15,16) that is, a pair for the body and one for each cornu. The chondrocytes begin the process of making the cartilaginous tissue in the hyoid bone during 5^{th} week of intrauterine life and is completed in the 3^{rd} and 4^{th} gestational months. The Ossification process begins first in the greater cornua of the hyoid bone from the two ossification centres, one in each cornu towards the end of the fetal development. The body of the hyoid bone ossifies next from the two ossification centres during the first or second year after the birth. The lesser cornua of the hyoid bone are the last to begin ossification from the two ossification centres during the peripubescent period. In early life the outer border of the body are connected to the greater horns by synchondrosis. After middle age, they unite by bony union(14,15,16).

Factors affecting bone ossification and development: There are number of external and internal factors that influence the ossification(14,15,16) and development of bones. They are hormonal changes, dietary factors, genetic factors, physical activity and exposure to sunlight. Nutrients such as Vitamin A and Vitamin D are essential for the growth and development of bones. Vitamin C is essential for the collagen formation. Thyroid hormones play an important role in the ossification of cartilage in the epiphyseal plate of the long bones. Paratharmone stimulates an upsurge and increase in the activity of osteoclasts.

FUNCTIONS OF THE HYOID BONE

Hyoid bone is found in almost all the mammalian population. One of the most important and unique function(3,17) of the hyoid bone is to serve as an anchoring structure for the tongue there by allowing a wide range of movements of tongue, pharyngeal and laryngeal structures. It also helps in other important functions (3,17)such as breathing, swallowing and production of speech. It helps in anchoring the hyoglossus muscle for creating a depression on the tongue so as to enlarge the oral cavity to accommodate, chew and swallow the food. The historical significance of the hyoid dates back to the age of Neanderthals(18) Hyoid bone was found to be responsible for their ability to speak by analysing the Neanderthal's fossilised hyoid bone. There was a close structural resemblance between the hyoid bones of Neanderthal and modern day humans. The discovery of hyoid bone of a Neanderthal man in the kebra cave(18) in Israel led its discoverers to believe that the Neanderthals(18) had a descended larynx, which gives human like – speech capabilities(13). However, other researchers oppose this theory and stressed out the necessity to take into consideration the factors like skull base, the mandible, the cervical vertebrae and a cranial reference plane for the above theory.

The hyoid bone is also thought to play a key role in keeping the upper airway open during sleep, and as such, the development and treatment of Obstructive Sleep Apnoea(19) (OSA; characterized by repetitive collapse of the upper airway during sleep). The involvement of hyoid bone in obstructive sleep apnoea was confirmed from the data's collected from number of studies

and research. It was further postulated that inferiorly positioned hyoid bone is strongly associated with presence and increased severity of obstructive sleep apnoea(19). Various experiments conducted on computer simulated models prove the involvement of hyoid bone in modifying upper airway properties. Hyoid suspension is a surgical procedure done to potentially increase and improve the airway for the patients having obstructive sleep apnoea(19).

IMPORTANCE OF THE HYOID BONE IN FORENSIC MEDICINE:

In forensic medicine, the hyoid bone is examined(20,21) carefully in manual strangulation(6-11) cases, where the bone may get fractured. Even though hyoid bone may get fractured in hanging cases also, its incidence is far less compared to manual strangulation. In manual strangulation(6-11) cases hyoid bone fractures occurs in older victims of strangulation(6-11) than young victims. The occurrences of fracture are less in female victims than male counterpart. The main reason behind this lies in the anatomy and ossification of hyoid bone. Many studies on the hyoid bone fractures(12) prove that, the fractures occur commonly in older age groups where the hyoid bones are fused. Whereas the fractures(12) are rare or absent in younger victims where the hyoid are unfused. Around 70% of hyoid bone fractures are seen in fused hyoid bones of older age group. Hence the ossification of hyoid bones plays as a key determining factor in the fracture process. Thus it is possible to understand why some victims of strangulation have fractured hyoid bone while others don’t have fractured hyoid bone

Apart from ossification, the shape of hyoid bone also provides valuable information in differentiating fractured and unfractured hyoid bones. The anterio-posterior length of the fractured hyoid bone is longer and steeply sloping than the normal hyoid bone. These above parameters help in solving the homicidal cases involving strangulation(6-11).

Before studying the fractures of hyoid bone, it is important to know about the strategic location of the hyoid bone in our body. Hyoid bone lies at the root of tongue and it has a central horizontal body to which are attached two long greater horns which sweeps backwards and slightly upwards above the upper margin of the thyroid cartilage. It has two lesser horns which are attached to the upper surface have no forensic significance. The horns of the hyoid calcify during middle and later part of the life.

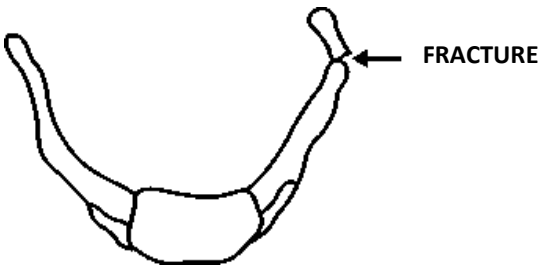
The various types of fractures(12) of hyoid bone are :

i) Inward compression fracture

ii) Outward compression fracture

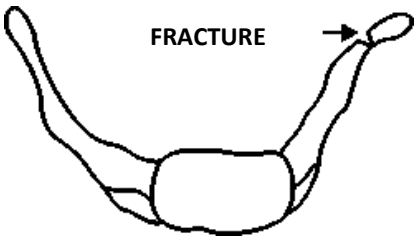
iii) Avulsion fracture

i) Inward compression fracture:



This type of fracture is commonly seen in manual strangulation or throttling. In this the greater horns of the hyoid bone are compressed inwards causing the fracture of the bone with tear of its periosteum on the outer side and not on the inner side thereby displacing the posterior fragments inwards. This type of fracture can occur on both the sides of the hyoid bone. The main reason for the occurrence of this fracture in throttling cases is, when the fingers of the assailant's hand grasps and squeezes the neck of the victim there produces an inward compression force which causes the fracture of the hyoid bone, displacing its posterior fragment inwards. A similar type of fracture may also be seen in the joint between greater horn of the hyoid and the body of the hyoid bone. In cases of decomposed body, it is difficult to say whether the fracture is ante mortem or post-mortem when the soft tissues are absent around the bone.

ii) Outward compression fracture:



This fracture is also known as antero- posterior compression fracture. It is commonly seen in cases of hanging and ligature strangulation. In the above cases there occurs a diverging force which acts on the hyoid bone causing fracture with outward displacement of small fragment of posterior part of the bone. As the result, the periosteum

of inner side of the fracture is torn leaving behind the periosteum(7-10) on the outer side intact. Due to which the fragment can be easily displaced outwards but inward movement is limited to normal position only. Either this type of fracture occurs in the greater horn at its junction with the body or it may be bilateral. When the compression force is severe the bony fragment may be completely detached from the bone and it may lie near to the rest of the bone, in such cases careful neck dissection and thorough insitu examination of the hyoid bone in the neck may reveal whether the fracture is due to inward or outward compression force(7-10). The outward fractures of the hyoid bone are also seen in run over road traffic accidents and severe blows on the front of the neck apart from hanging, in these cases the hyoid bone will be grossly fractured with outward displacement of the bony fragment, along with multiple fractures of the other structures of the body.

iii) Avulsion fractures:

It occurs due to muscular over activity without any direct injury to the hyoid bone. It is also known as tug or traction fracture. This fracture occurs as a result of traction on the thyrohyoid ligament either by downward or lateral movement of the thyroid cartilage from anteroposterior or lateral compression or when direct pressure is exerted between the hyoid and thyroid by the pressing fingers. This is a type of bilateral fracture in which, one greater horn is

fractured outwards and the other inwards. The presence of cartilaginous separation, incomplete bony union of the hyoid parts and the joints between the lesser horns and the body should not be mistaken for fractures(7-10). The proper and meticulous dissection of the neck is important to avoid producing any post-mortem artefacts in the hyoid bone such as post-mortem fractures of the hyoid bone etc. The fractured hyoid bone and its surrounding soft tissues must be examined for contusion to prove that it is of antemortem(22) in nature.

Fig: VI- Male and Female hyoid bones after removal of soft tissues

Previous studies done on the hyoid bone for sex Determination

Many studies were done and recorded on sexual dimorphism in the hyoid bone. The first study involving the age and sex related variations in the hyoid bone morphology was done by **Miller et al.(28)** in the year 1998. In this study, a total of 315 hyoid bones (188 male bones and 127 female bones) were taken and studied. In each case, the bone was carefully dissected from the neck and the surrounding soft tissues were removed. Each specimen was radiographed from the X-ray source(28). The radiographs were then converted in to digital images using a high resolution scanner and measured using sigma scan image analysis system. A series of 30 measurements were taken from the radiographs of 315 hyoid bones from the people of known age and sex. The measurements were finally analysed and compared. The study showed that, the distal ends of the greater cornua of the female hyoid bones were larger than the male hyoid bones, while the portion of the bone proximal to this was found to be larger in males than in females. It showed that, the female hyoid bones have relatively long and thin distal segments.

Table 1- Measurements of Miller et al. study(28)

	Average maximum Cornual length (in cm)	**Average vertical height of the body of the hyoid bone (in cm)**	**Average transverse width of the body of the hyoid bone (in cm)**
Male Hyoid Bones	2.83	0.79	2.14
Female Hyoid Bones	2.74	0.74	1.98

Gad El-Hak et al. - This study was done on 33 (22 males and 11 females) hyoid bones belonging to the age group of 14 to 70 years in the Egyptian population. The bones were dissected and analysed using radiography method. It is considered as a preliminary study to evaluate the sexual dimorphism by studying the morphology and fusion of the hyoid bones in both sexes.

The width and length parameters of the hyoid bones were taken in to consideration. The results showed that, the measurements such as, the width of the hyoid bone and the length of the hyoid bone has greatest sexual dimorphism with statistical significance (<0.05). Females tend to have smaller hyoid bones in both parameters with no statistical significance difference in both sexes. In contrast, miller et. al showed that the distal ends of the greater cornua are more sexually dimorphic than the other parameters.

The study showed that the hyoid bone shape is related to the parabolic type in both sexes. In contrast, Papadopoulos et al(23)., (1989) found that the common type of hyoid bone shape in women is the hyperbolic type while in men it is parabolic type.

Harjeet and Jit I. Study-

In an article reported by Harjeet and Jit I(25)- size, shape and sexual dimorphism of the hyoid bone in adult northwest Indians, it was found that all the measurements(25) were greater in the males than in the females. This study was done on the hyoid bones collected from the department of forensic medicine, Postgraduate Institute of Medical Education, Chandigarh .

Table 2- Measurements of Harjeet and Jit I study

	Maximum Cornual length (in cm)	Vertical height of the body (in cm)	Transverse width of the body (in cm)	Length of the hyoid bone (in cm)	Width of the hyoid bone (in cm)
Male Hyoid Bones	3.37± 0.28	1.10±0.11	2.40±0.23.	3.86±0.32	3.72±0.58
Female Hyoid Bones	2.97±0.27	0.94±0.10	2.02±0.15	3.40±0.28	3.18±0.47

. Till 1988, most of the research on hyoid bone was done by the international authors. In 1988, Ranjith. C and Pillai. S(32) and in 1996, Harjeet and Jit I Worked on the weight and morphometrics of the hyoid bone.

Mukhopadhyay et al. -

In a study done on Bengali population(33), 50 hyoid bones were examined. The results show that 90% of the cases were correctly identified in to the two sexes by means of five predictors viz. Overall width, length of the greater cornua, anteroposterior length, width of the body of hyoid and the distance between the lesser cornua. All the parameters included in this are greater in males than females(33). Direct measurements done on the hyoid bones in autopsy cases are more precise and reliable than the earlier works on measurements of hyoid bones using X-ray radiography. In the above study they reported that, with a single parameter namely, the length of the greater cornu or the width of the bone or the weight of the hyoid bone, the sex could be determined in 11 to 37 percent of the bones.

Priya et al. study – This study(26) was done on 100 hyoid bones in different age groups (15-75 years) obtained from the autopsies conducted in Guntur medical college. It was proved that, all the parameters were greater in males than females. In most of the parameters, there was a clear cut demarcation between the values of male and female hyoid bones. The transverse distance between the tubercles of greater cornua (width of the hyoid bone) in males was 46.32±0.31 mm compared to 38.01±5.28 mm in females. Similarly the height of the body of the hyoid bone in males was found to be 11.85 ± 1.53mm compared to 10.04± 1.01 mm in females. The study(26) also showed that, the sex can be determined with maximum accuracy by taking the different parameters of hyoid bone but accuracy is not attained, if only one parameter is taken in to consideration

Amrutha Roopa et al.-In another study(12) conducted on 83 cases on the hyoid bone by the department of anatomy, Chalmela Ananda Rao Institute of medical sciences, Andhra Pradesh, metric analysis(12) study showed, the length, width and the thickness of the greater cornua of the hyoid bone were more in males when compared to females. The measurements are either highly significant($p<0.001$) or significant($p<0.001$ and $p<0.005$). It was also found out that the above measurements increase in their dimensions with increase in age in males but in females there is a variation of size only in the length of greater and lesser cornua up to 25 years of age.

The range, mean, standard deviation and level of significance of all the fifteen parameters of the hyoid bone were calculated using the standard

statistical method. All the previous reports are unanimous on this. The greater size in males is a feature predominantly observed in bones of the human skeleton.

Table 3- Measurements of Amrutha Roopa study

	Average maximum Cornual length (in cm)	**vertical height of the body (in cm)**	**transverse width of the body (in cm)**	**Length of the hyoid bone (in cm)**	**Width of the hyoid bone (in cm)**
Male Hyoid Bones	3.20±-0.25	1.18±0.15	2.26±0.31	3.68±0.31	3.72±0.77
Female Hyoid Bones	2.87±0.24	1.00±0.17	2.03±0.15	3.23±0.24	3.27±0.56

Kim et al., (2006)- This study was focused on sex- based morphometry of the hyoid bone, was done in Koreans(27) using digital photographs . Hyoid bones from 52 males and 33 females were examined(27). Thirty four measurements from photographs using computer program were taken. 21 of 34 measurements had significant sex differences. The accuracy of discriminant functions was 88.2% in both groups, proving that those could be used to distinguish men from women in a statistically significant manner.

In a study conducted on the morphology of the hyoid bone with regard to forensic application by the department of anatomy, Nagpur medical college, it was found that the most common pattern of hyoid bone is of hyperbola type in either sex and the boat type is least common among different shapes found in

the hyoid bone. It was also concluded that the second leading form is the parabola type in males and the horseshoe type in females.

A study was conducted using 398(23,24) hyoid bones, in which 10 parameters were taken for consideration. Of these, 169 hyoid bones were fused completely (Both greater cornu fused to the body of hyoid) and 229 bones were not fused (Either one or neither of the greater cornu were fused with the body). Hyoid bones are classified based on sex using discriminant function analysis, where the accuracy was found out to be 82% t0 85%. This study also proves the existence of sexual differentiation in both fused and unfused hyoid bones of both sexes.

AIMS & OBJECTIVES

AIM:

I) To establish a method of sex determination from the osteometric measurements of the hyoid bone.

II) In the present study, an analysis of sexual dimorphism of the hyoid bone has been attempted using following parameters:

a) The average maximal cornual length of the hyoid bone

b) The Width of the hyoid bone

c) The Length of the hyoid bone

d) The transverse width of the body of the hyoid bone

e) The vertical height of the body of the hyoid bone

MATERIALS AND METHODOLOGY

STUDY SETTING

The present study was carried out in the institute of forensic medicine, Madras medical college and Rajiv Gandhi Government General Hospital, Chennai-03.

STUDY DESIGN

A prospective study, done to analyse the sexual dimorphism in the hyoid bones using various measurements, that were collected during the study period and to establish a method of sex determination from the above measurements. descriptive statistics of length of the hyoid, width of the hyoid, average maximum cornual length, height and width of the body of hyoid bone were analysed and recorded in terms of mean and standard deviation.

STUDY DURATION

The duration of the study was one year, extending from april-2017 to March-2018

STUDY POPULATION

The study was conducted on the medicolegal Cases in the age group of 18-60 years, subjected to medicolegal autopsy at the mortuary attached to Rajiv Gandhi Government General Hospital.

INCLUSION CRITERIA

All cases in the age group of 18-60 years, subjected for medico-legal autopsy

EXCLUSION CRITERIA

Cases where hyoid bones are fractured mainly of hanging and strangulation were excluded from the study

SAMPLE SIZE

A Sample size of 200 cases, subjected to medicolegal autopsy were included in the study

DATA COLLECTION

The present study was conducted for the period of one year, from april-2017 to march-2018, in the institute of forensic medicine, madras medical college and Rajiv Gandhi Government General Hospital, Chennai-03. During this period, the hyoid bones were collected from all the cases in the age group of 18-60 years which are subjected to medico legal autopsies. Before starting the autopsy, the general particulars about the deceased such as age and sex were collected and recorded. General details about the case were collected from the documents produced by the police at the time of autopsy.

DISSECTION TECHNIQUE

Dissection of hyoid bone was done by the following method suggested in the text book-Post Mortem Technique Handbook By Otto Saphire, (31)

- A wooden block of 10-15 cm in height was kept under the shoulders, to allow the head to fall back and thus the neck was extended.
- A modified "Y" shaped incision was made in the midline, extending from the Suprasternal notch over the clavicle to its centre on both sides and then passes upwards over the neck behind the ear.
- The skin flap was raised upwards and backwards, exposing the muscles of neck. All the muscles of the neck were carefully dissected in layers.
- Then, the trachea was identified in the midline and followed upward; Thyroid cartilage was identified from the upper end of the trachea. The hyoid bone was palpated immediately above the thyroid cartilage. The muscle attachments and the soft tissues were cut and separated from the hyoid bone.
- Care must be taken not to damage the greater cornua during dissection.
- Hyoid bones are then stored in 10% formalin solution for 72 hrs. This was followed by cleaning and wiping to make the bone dry and clean.

The bones were kept on a flat surface in their respective anatomical position, while taking the measurements. Direct measurements were taken by a battery operated digital vernier caliper (Precision of one mm) and measurement

scale. A total of three readings were taken and average of three reading were recorded.

Pic- 1 Male hyoid bone before the removal of soft tissues

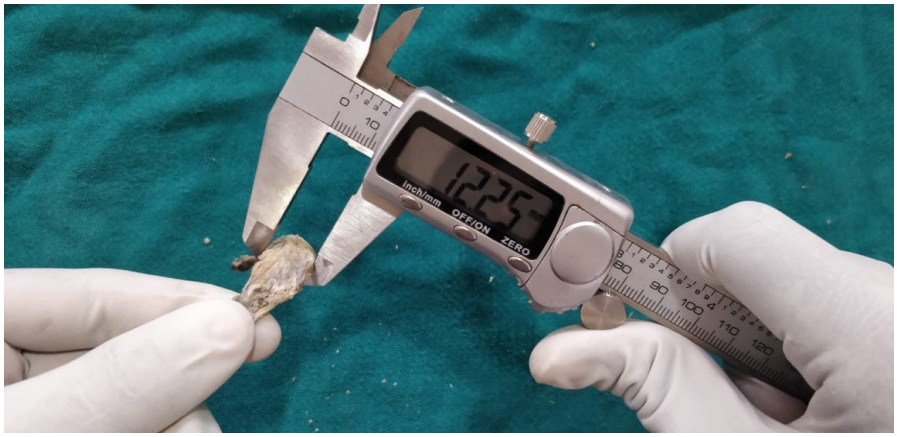
The following measurements were taken in the hyoid bone using digital vernier caliper:

1. **The Average maximum cornual length:** It is the average maximal cornual length of both right and left cornua (calculated from length of right and left greater cornua)
2. **The Width of the hyoid bone :** It is the distance between the distal ends of the greater cornu
3. **The Length of the hyoid bone:** Distance in the anteroposterior plane from the anterior middle of the body of the hyoid to the point lying mid-way between the tips of the hyoid bone
4. **The Height of the body of the hyoid bone**
5. **The Width of the body of the hyoid bone at its midpoint**

Pic-2 Male hyoid bones after removal of soft tissues

Pic-3 Vernier Caliper used for measuring the hyoid bone

Pic- 4 Estimation of cornual length of the male hyoid bone



Pic-5 Estimation of height of the body of the female hyoid bone

Pic-6 Estimation of the length of the female hyoid bone

Pic-7 Estimation of transverse width of the body of the hyoid bone

Pic-8 Estimation of the width of the body of the hyoid bone

Statistical analysis

The following datas were collected for statistical analysis and interpretation:

- Parameters such as average maximum cornual length , length of the hyoid bone, width of the hyoid bone, height of the body of hyoid bone and width of the body of hyoid bone are measured
- From each of the above five parameters of the hyoid bone, the mean, standard deviation and standard error were calculated for both sexes and tabulated
- The datas collected were divided in to six groups with an age intervals of seven years as: 18- 25, 26-32, 33-39, 40-46, 47-53, 54-60 years respectively. The mean and standard deviation were collected for each of the five parameters for each of the age groups to find out age related variations in the measurements. Thus, descriptive statistics of length of the hyoid, width of the hyoid, average maximum cornual length, height

and width of the body of hyoid bone were analysed and recorded in terms of mean and standard deviation.(Table-7 to Table-16)

- Analysis of Variance (ANOVA) was used to prove that the differences between the age groups was statistically significant for each of the parameters(Table-25 to Table-34)
- Independent “t” test would be used to compare the mean cornual length, the width of hyoid bone, the length of the hyoid bone, the height of the body of the hyoid bone and the transverse width of the body of the hyoid bone.(Table-35 to Table-39)
- Discriminant analysis was done to find the sexual dimorphism in each of five parameters. The ultimate purpose was to find out which of the five parameters show greatest sexual dimorphism(Table -23 and Table-24)

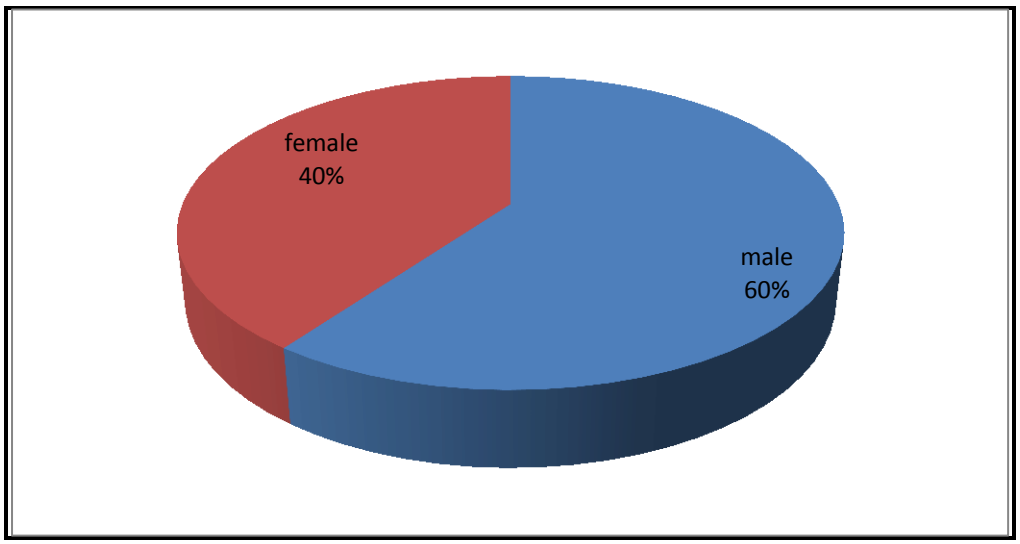
OBSERVATION AND RESULTS

The data has been recorded systematically and various observations were made and tabulated.

Tab - 4 Distribution of sex among the study groups

S.NO	SEX	NO OF CASES	PERCENTAGE
1.	MALE	120	60
2.	FEMALE	80	40
	TOTAL	200	100

Fig-4 Distribution of sex among the study groups

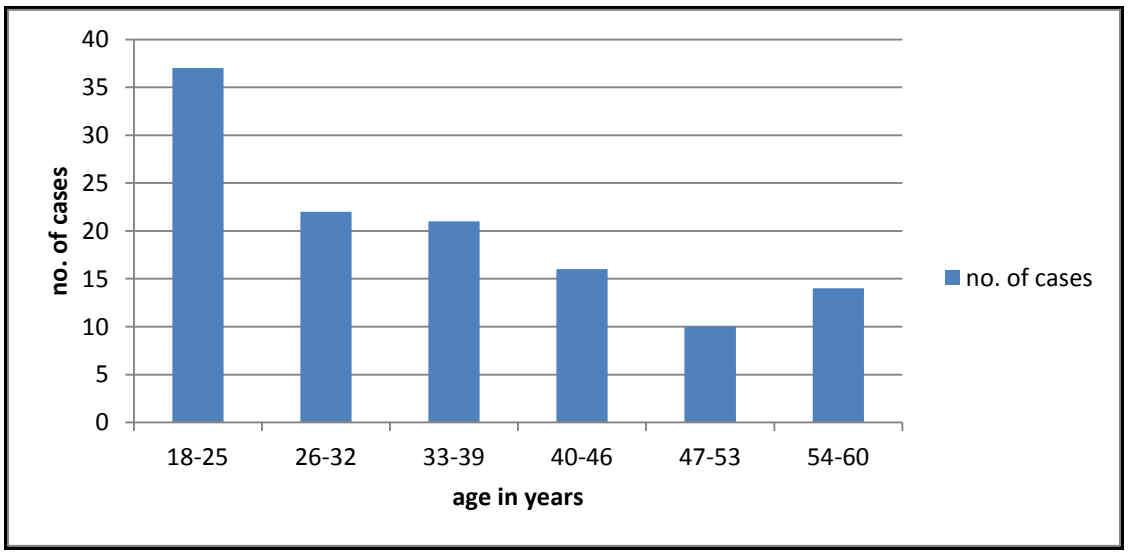


Above Table- IV and Fig-IV shows the distribution of sex among the study cases In our study sample of 200 cases, the total numbers of male(blue) cases were 120, which forms 60 percent of the sample and the total number of female(red) cases were 80, which forms forty percent of the study sample. There are more number of male cases recorded, as they are more prone to road traffic accidents and work place injuries.

Table-5 Age group wise distribution of the study sample in males

S.NO	AGE GROUPS (IN YEARS)	NO.OF MALES
1	18-25	37
2	26-32	22
3	33-39	21
4	40-46	16
5	47-53	10
6	54-60	14
Total		120

Fig-5 Age group wise distribution of the study sample in males

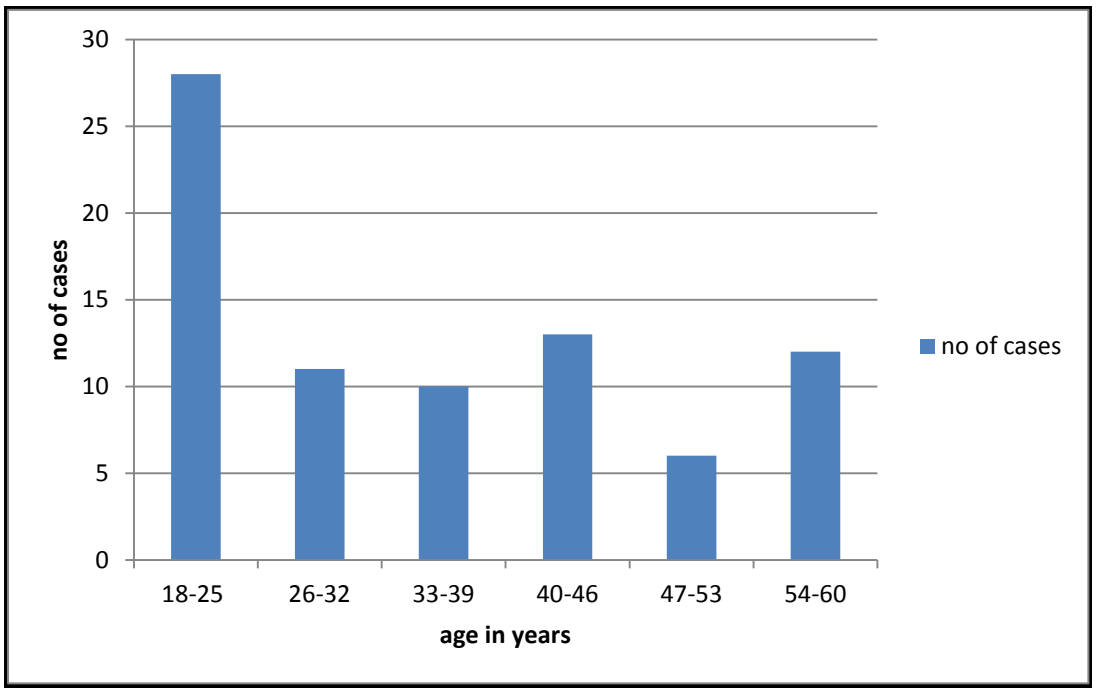


Above Table –5 and Fig-5 shows the distribution of age in to six groups with an age interval of seven years in the total male cases. There was more number of deaths recorded in the age group of 18 to 25 years than the other age groups.

Table-6 Age group wise distribution of the study sample in females

S.NO	AGE GROUPS (IN YEARS)	NO.OF FEMALES
1	18-25	28
2	26-32	11
3	33-39	10
4	40-46	13
5	47-53	6
6	54-60	12
Total		80

Fig-6 Age group wise distribution of the study sample in females

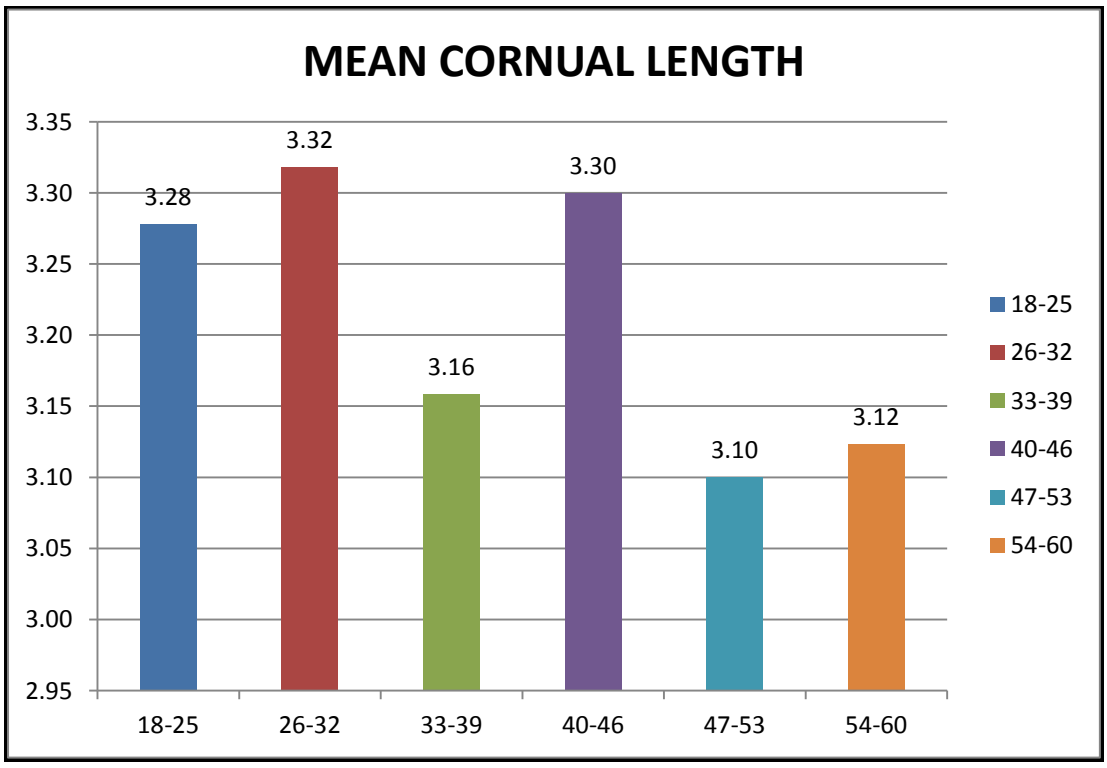


Statistical Analysis for each of the age groups for Male and Female bones

Tab-7 Summary for Average maximal cornual length in male cases

Group No.	Age Group	Mean (In cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	3.28	0.23	37
2.	26-32 Years	3.32	0.28	22
3.	33-39 Years	3.16	0.21	21
4.	40-46 Years	3.30	0.29	16
5.	47-53 Years	3.10	0.19	10
6.	54-60 Years	3.12	0.21	14
	18-60 Years	**3.22**	**0.25**	**120**

Fig-7 Summary for Mean cornual length in male cases

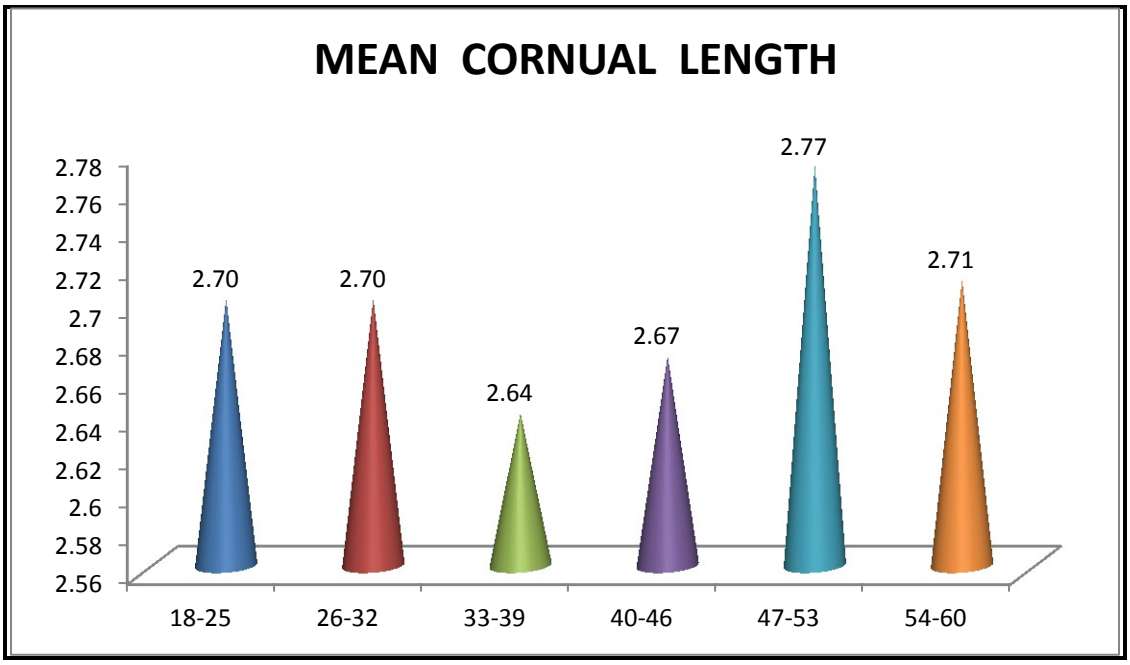


The above **Tab-7 and Fig-7** represents the summary of mean cornual length along with standard deviation of the hyoid bone for various age groups in the male cases**.** Mean cornual length with standard deviation for all the age groups in male cases were calculated and entered. Finally the mean cornual length of entire male cases were calculated from all the age groups. The mean cornual length of the age group 18-25 years was found to be 3.28±0.23 cm, the mean cornual length of the age group 26-32 years was 3.32±0.28 cm, the mean cornual length of the age group 33 to 39 years was 3.16±0.21 cm, the mean cornual length of the age group 40-46 years was 3.30±0.29 cm, the mean cornual length of the age group 47-53 years was 3.10±0.19 cm, the mean cornual length of the age group 54-60 years was 3.12±0.21 cm. The mean cornual length of the entire male cases was 3.22±0.25 cm.

Tab-8 Summary for Average maximal cornual length in female cases

Group No.	**Age Group**	**Mean (in cm)**	**Standard Deviation**	**No. Of Cases**
1.	18-25 Years	2.70	0.30	28
2.	26-32 Years	2.70	0.30	11
3.	33-39 Years	2.64	0.15	10
4.	40-46 Years	2.67	0.23	13
5.	47-53 Years	2.77	0.27	6
6.	54-60 Years	2.71	0.32	12
	18-60 Years	**2.69**	**0.27**	**80**

Fig-8 Summary for Average maximal Cornual length in female cases

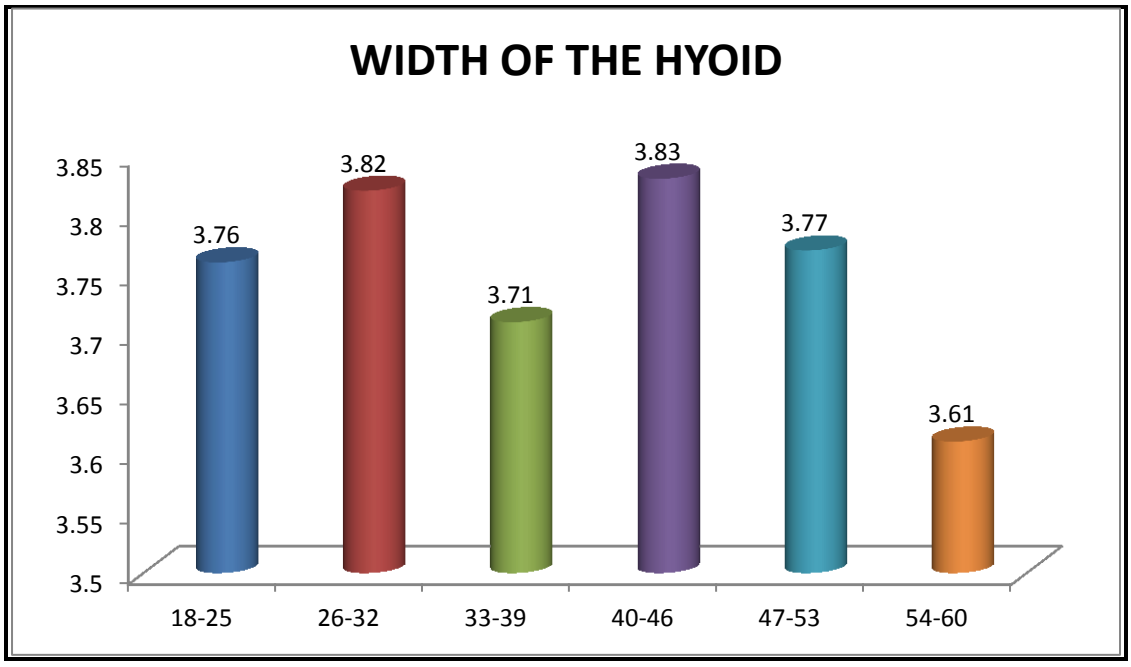


The above **Tab-8 and Fig-8** represents the summary of mean cornual length along with standard deviation of the hyoid bone for various age groups in the female cases**.** Mean cornual length with standard deviation for all the age groups in female cases were calculated and entered. Finally the mean cornual length of entire female cases was calculated from all the age groups. The mean cornual length of the age group 18-25 years was found to be 2.70±0.30 cm, the mean cornual length of the age group 26-32 years was 2.70±0.30 cm, the mean cornual length of the age group 33 to 39 years was 2.64±0.15 cm, the mean cornual length of the age group 40-46 years was 2.67 ±0.23cm, the mean cornual length of the age group 47-53 years was 2.77 ±0.27cm, the mean cornual length of the age group 54-60 years was 2.71±0.32 cm The mean cornual length of the entire female cases was 2.69±0.27 cm.

Tab-9 Summary for Mean width of the hyoid bone in male cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	3.76	0.27	37
2.	26-32 Years	3.82	0.25	22
3.	33-39 Years	3.71	0.25	21
4.	40-46 Years	3.83	0.50	16
5.	47-53 Years	3.77	0.40	10
6.	54-60 Years	3.61	0.32	14
	18-60 Years	**3.75**	**0.32**	**120**

Fig-9 Summary for Mean width of the hyoid bone in male cases



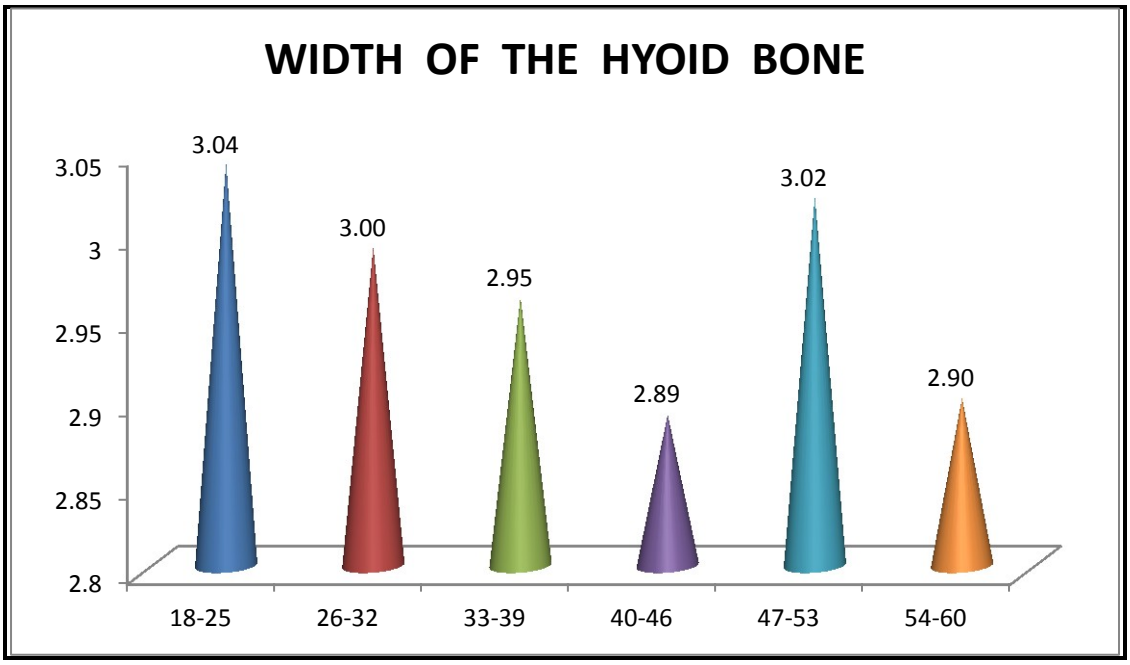
The above **Tab-9 and Fig-9** represents the summary of mean width of the hyoid bone along with standard deviation for various age groups in the male

cases**.** The mean width of the hyoid bone along with standard deviation for all the age groups in male cases were calculated and entered. Finally, the mean width of the hyoid bone of entire male cases were calculated from all the age groups. The mean width of the hyoid bone of the age group 18-25 years was found to be 3.76±0.27 cm, the mean width of the hyoid bone of the age group 26-32 years was 3.82±0.25 cm, the mean width of the hyoid bone of the age group 33 to 39 years was 3.71±0.25 cm, the mean width of the hyoid bone of the age group 40-46 years was 3.83±0.50 cm, the mean width of the hyoid bone of the age group 47-53 years was 3.77±0.40 cm, the mean width of the hyoid bone of the age group 54-60 years was 3.61±0.32 cm. The mean width of the hyoid bone of the entire male cases was 3.75±0.32 cm.

Tab-10 Summary for Mean width of the hyoid bone in female cases

Group No.	**Age Group**	**Mean (in cm)**	**Standard Deviation**	**No. Of Cases**
1.	18-25 Years	3.04	0.28	28
2.	26-32 Years	3.00	0.20	11
3.	33-39 Years	2.95	0.21	10
4.	40-46 Years	2.89	0.31	13
5.	47-53 Years	3.02	0.23	6
6.	54-60 Years	2.90	0.44	12
	18-60 Years	**2.97**	**0.29**	**80**

Fig-10 Summary for Mean width of the hyoid bone in female cases

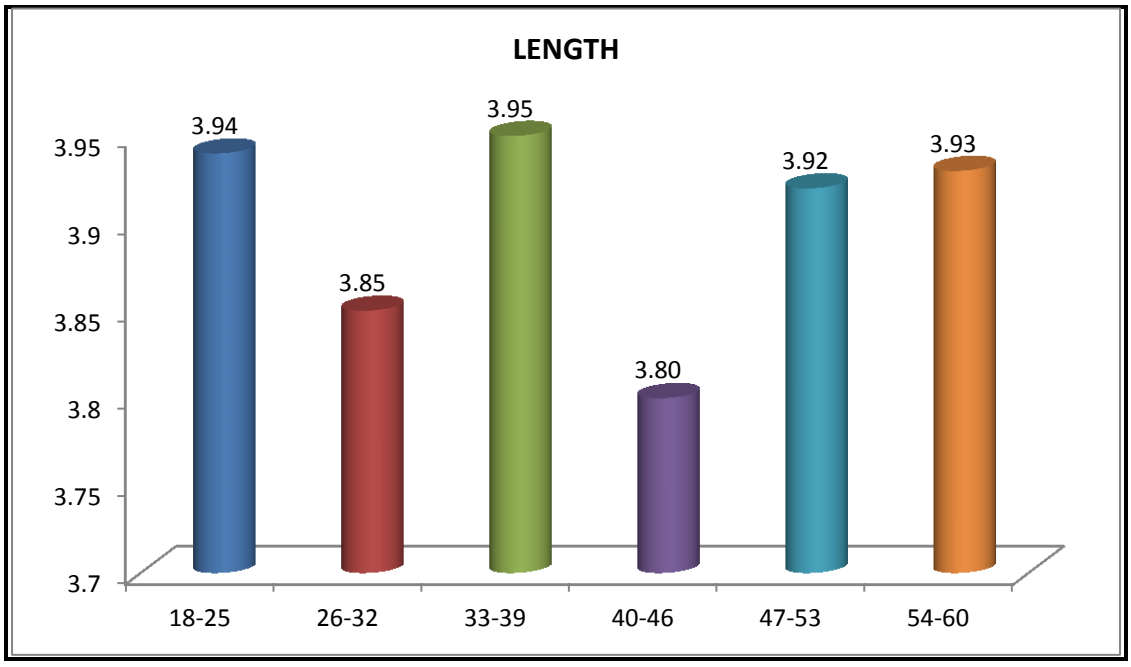


The above **Tab-10 and Fig-10** represents the summary of mean width of the hyoid bone along with standard deviation for various age groups in the female cases**.** The mean width of the hyoid bone along with standard deviation for all the age groups in female cases were calculated and entered. Finally, the mean width of the hyoid bone of entire female cases were calculated from all the age groups. The mean width of the hyoid bone of the age group 18-25 years was found to be 3.04±0.28 cm, the mean width of the hyoid bone of the age group 26-32 years was 3.00±0.20 cm, the mean width of the hyoid bone of the age group 33 to 39 years was 2.95±0.21±0.21 cm, the mean width of the hyoid bone of the age group 40-46 years was 2.89±0.31 cm, the mean width of the hyoid bone of the age group 47-53 years was 3.02±0.23 cm, the mean width of the hyoid bone of the age group 54-60 years was 2.90±0.44 cm. The mean width of the hyoid bone of the entire female cases was 2.97±0.29 cm.

Tab-11 Summary for Mean length of the hyoid bone in male cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	3.94	0.21	37
2.	26-32 Years	3.85	0.20	22
3.	33-39 Years	3.95	0.26	21
4.	40-46 Years	3.80	0.22	16
5.	47-53 Years	3.92	0.27	10
6.	54-60 Years	3.93	0.27	14
	18-60 Years	**3.90**	**0.23**	**120**

Fig-11 Summary for Mean length of the hyoid bone in male cases



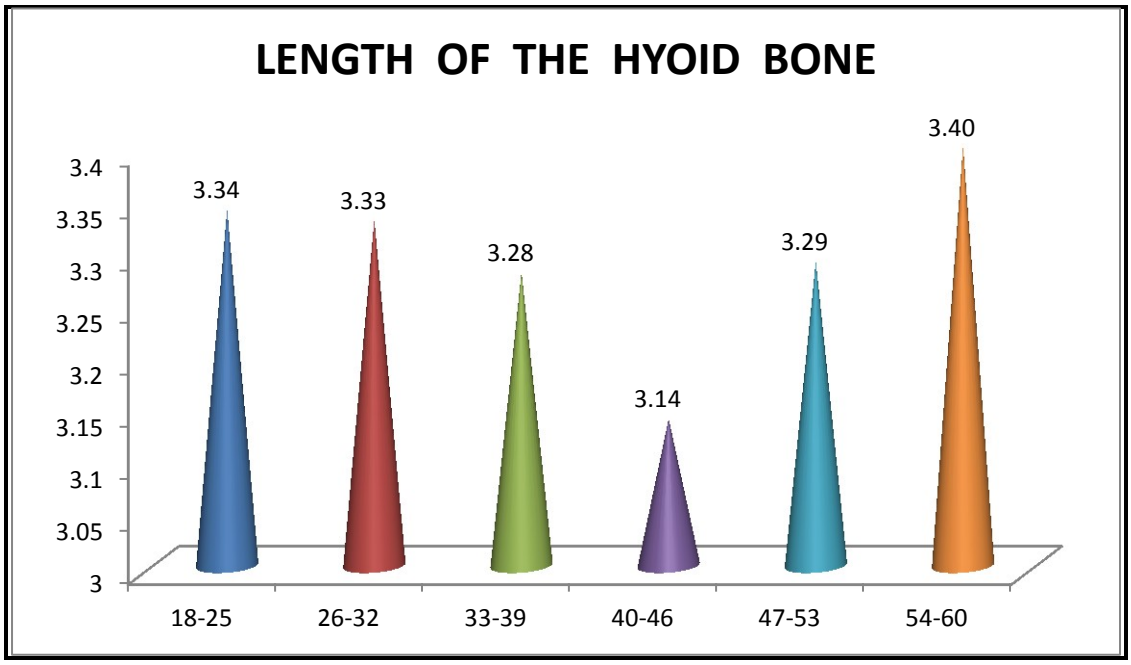
The above **Tab-11 and Fig-11** represents the summary of mean length of the hyoid bone along with standard deviation for various age groups in the male

cases**.** The mean length the hyoid bone along with standard deviation for all the age groups in male cases were calculated and entered. Finally, the mean length of the hyoid bone of entire male cases were calculated from all the age groups. The mean length of the hyoid bone of the age group 18-25 years was found to be 3.94±0.21 cm, the mean length of the hyoid bone of the age group 26-32 years was 3.85±0.20 cm, the mean length of the hyoid bone of the age group 33 to 39 years was 3.95±0.26 cm, the mean length of the hyoid bone of the age group 40-46 years was 3.80±0.22 cm, the mean length of the hyoid bone of the age group 47-53 years was 3.92±0.27 cm, the mean length of the hyoid bone of the age group 54-60 years was 3.93±0.27 cm. The mean length of the hyoid bone of the entire male cases was 3.90±0.23 cm.

Tab-12 Summary for Mean length of the hyoid bone in female cases

Group No.	**Age Group**	**Mean (in cm)**	**Standard Deviation**	**No. Of Cases**
1.	18-25 Years	3.34	0.25	28
2.	26-32 Years	3.33	0.16	11
3.	33-39 Years	3.28	0.24	10
4.	40-46 Years	3.14	0.23	13
5.	47-53 Years	3.29	0.24	6
6.	54-60 Years	3.40	0.32	12
	18-60 Years	**3.30**	**0.25**	**80**

Fig-12 Summary for Mean length of the hyoid bone in female cases

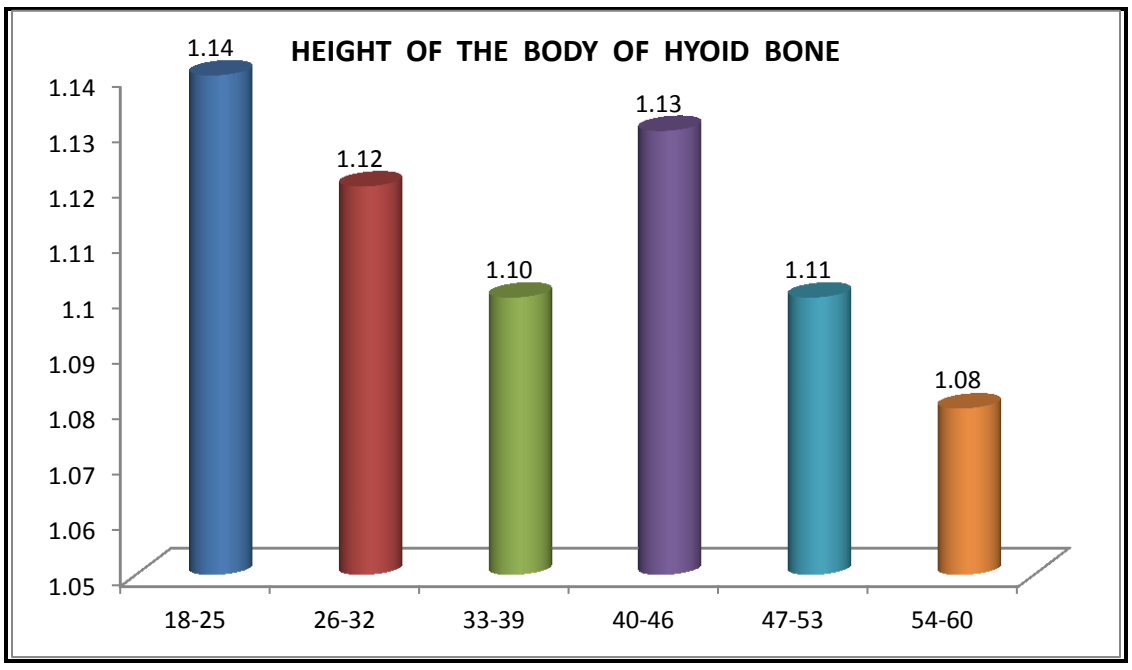


The above **Tab-12 and Fig-12** represents the summary of mean length of the hyoid bone along with standard deviation for various age groups in the female cases**.** The mean length the hyoid bone along with standard deviation for all the age groups in female cases were calculated and entered. Finally, the mean length of the hyoid bone of entire female cases were calculated from all the age groups. The mean length of the hyoid bone of the age group 18-25 years was found to be 3.34±0.25 cm, the mean length of the hyoid bone of the age group 26-32 years was 3.33±0.16 cm, the mean length of the hyoid bone of the age group 33 to 39 years was 3.28±0.24 cm, the mean length of the hyoid bone of the age group 40-46 years was 3.14±0.23 cm, the mean length of the hyoid bone of the age group 47-53 years was 3.29±0.24 cm, the mean length of the hyoid bone of the age group 54-60 years was 3.40±0.32 cm. The mean length of the hyoid bone of the entire male cases was 3.30±0.25 cm.

Tab-13 Summary for Mean vertical height of the hyoid bone in male cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	1.14	0.09	37
2.	26-32 Years	1.12	0.11	22
3.	33-39 Years	1.10	0.11	21
4.	40-46 Years	1.13	0.10	16
5.	47-53 Years	1.10	0.10	10
6.	54-60 Years	1.08	0.10	14
	18-60 Years	**1.11**	**0.10**	**120**

Fig-13 Summary for Mean vertical height of the hyoid bone in male cases

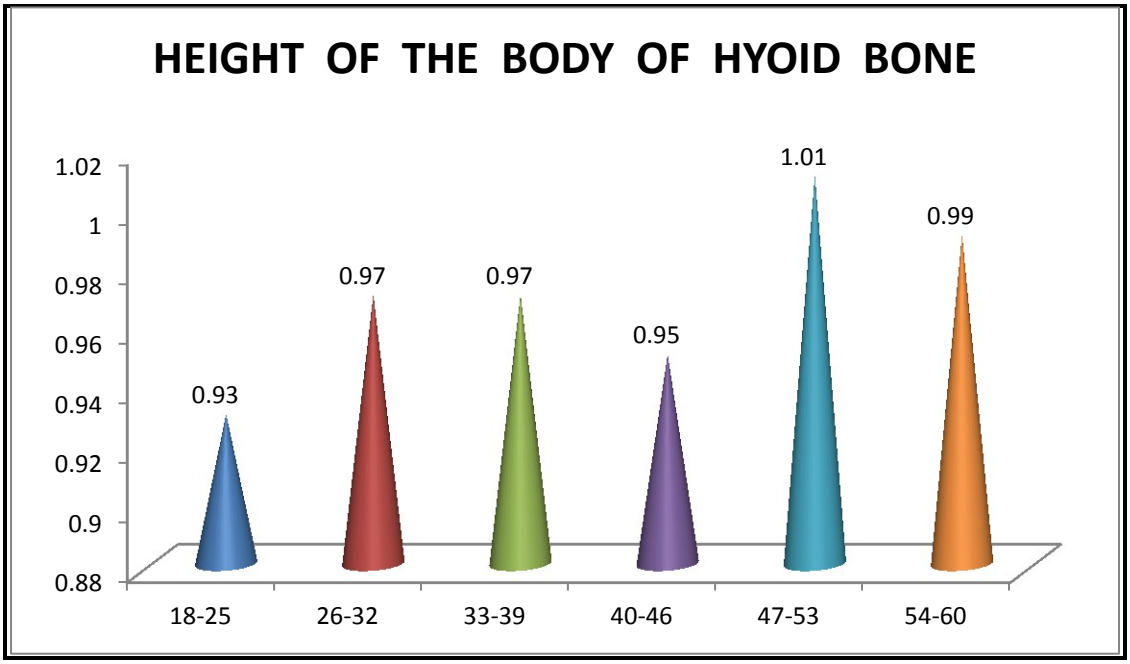


The above **Tab-13 and Fig-13** represents the summary of mean height of the body of the hyoid bone along with standard deviation for various age groups in the male cases**.** The mean height of the body of the hyoid bone along with standard deviation for all the age groups in male cases were calculated and entered. Finally, the mean height of the body of the hyoid bone of entire male cases were calculated from all the age groups. The mean height of the body of the age group 18-25 years was found to be 1.14±0.09 cm, the mean height of the body of the age group 26-32 years was 1.12±0.11 cm, the mean height of the body of the age group 33 to 39 years was 1.10±0.11 cm, the mean height of the body of the age group 40-46 years was 1.13±0.10 cm, the mean height of the body of the age group 47-53 years was 1.10±0.10 cm, the mean height of the body of the age group 54-60 years was 1.08±0.10 cm. The mean height of the body of the entire male cases was 1.11±0.10 cm.

Tab-14 Summary for Mean vertical height of the body of hyoid bone in female cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	0.93	0.19	28
2.	26-32 Years	0.97	0.08	11
3.	33-39 Years	0.97	0.08	10
4.	40-46 Years	0.95	0.06	13
5.	47-53 Years	1.01	0.09	6
6.	54-60 Years	0.99	0.06	12
	18-60 Years	**0.96**	**0.13**	**80**

Fig-XIV Summary for Mean vertical height of the body of hyoid bone in female cases

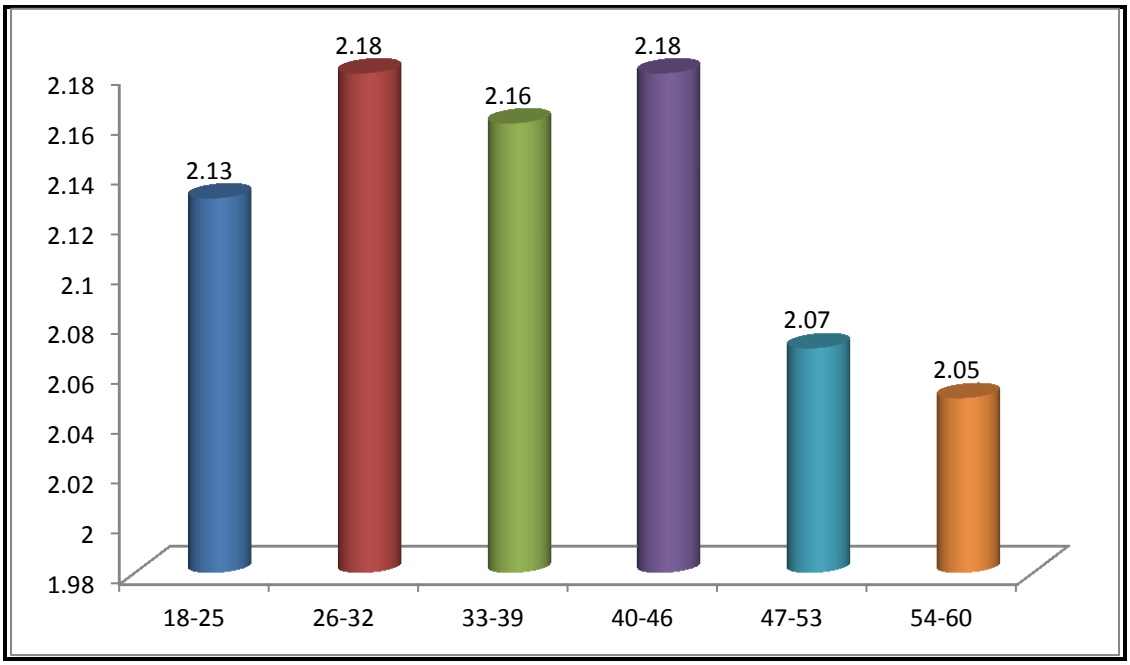


The above **Tab-14 and Fig-14** represents the summary of mean height of the body of the hyoid bone along with standard deviation for various age groups in the female cases**.** The mean height of the body of the hyoid bone along with standard deviation for all the age groups in female cases were calculated and entered. Finally, the mean height of the body of the hyoid bone of entire female cases were calculated from all the age groups. The mean height of the body of the age group 18-25 years was found to be 0.93±0.19 cm, the mean height of the body of the age group 26-32 years was 0.97±0.08 cm, the mean height of the body of the age group 33 to 39 years was 0.97±0.08 cm, the mean height of the body of the age group 40-46 years was 0.95±0.06 cm, the mean height of the body of the age group 47-53 years was 1.01±0.09 cm, the mean height of the body of the age group 54-60 years was 0.99±0.06 cm. The mean height of the body of hyoid bone of the entire female cases was 0.96±0.13 cm.

Tab-15 Summary for Mean transverse width of the body of the hyoid bone in male cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	2.13	0.30	37
2.	26-32 Years	2.18	0.34	22
3.	33-39 Years	2.16	0.20	21
4.	40-46 Years	2.18	0.23	16
5.	47-53 Years	2.07	0.12	10
6.	54-60 Years	2.05	0.32	14
	18-60 Years	**2.13**	**0.28**	**120**

Fig-15 Summary for Mean transverse width of the body of the hyoid bone in male cases



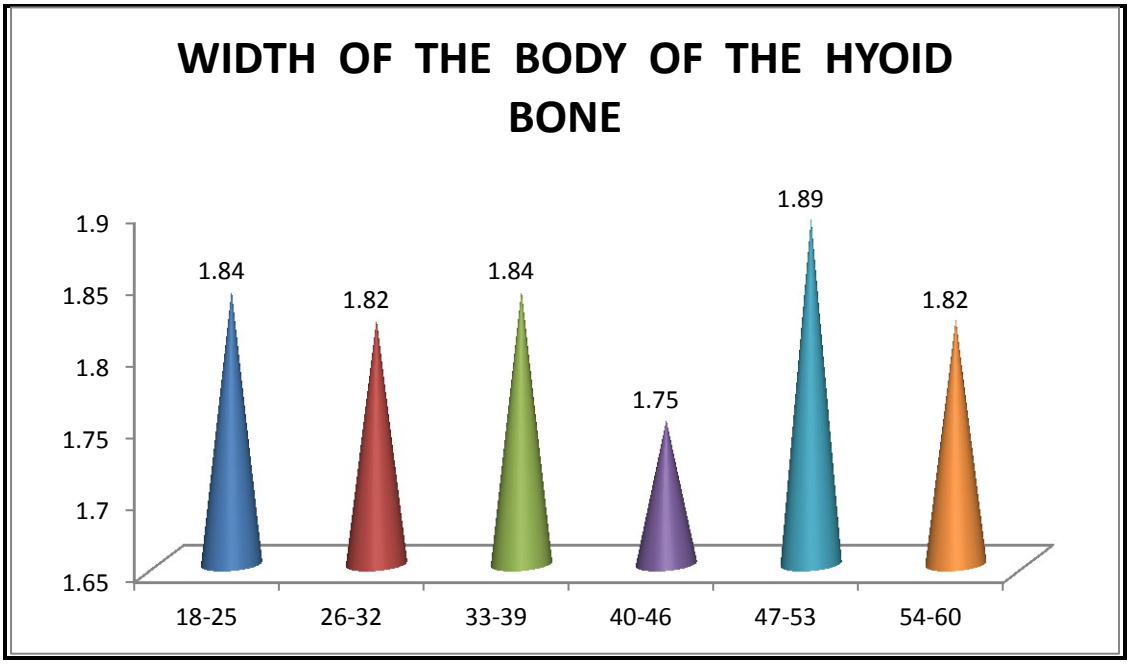
The above **Tab-15 and Fig-15** represents the summary of mean width of the body of the hyoid bone along with standard deviation for various age groups in the male cases**.** The mean width of the body of the hyoid bone along with

standard deviation for all the age groups in male cases were calculated and entered. Finally, the mean width of the body of the hyoid bone of entire male cases were calculated from all the age groups. The mean width of the body of the age group 18-25 years was found to be 2.13±0.30 cm, the mean width of the body of the age group 26-32 years was 2.18±0.34 cm, the mean width of the body of the age group 33 to 39 years was 2.16±0.20 cm, the mean width of the body of the age group 40-46 years was 2.18±0.23 cm, the mean width of the body of the age group 47-53 years was 2.07±0.12 cm, the mean width of the body of the age group 54-60 years was 2.05±0.32 cm. The mean width of the body of hyoid bone of the entire male cases was 2.13±0.28 cm.

Tab-16 Summary for Mean transverse width of the body of the hyoid bone in female cases

Group No.	Age Group	Mean (in cm)	Standard Deviation	No. Of Cases
1.	18-25 Years	1.84	0.17	28
2.	26-32 Years	1.82	0.15	11
3.	33-39 Years	1.84	0.13	10
4.	40-46 Years	1.75	0.16	13
5.	47-53 Years	1.89	0.07	6
6.	54-60 Years	1.82	0.17	12
	18-60 Years	**1.82**	**0.15**	**80**

Tab-16 Summary for Mean transverse width of the body of the hyoid bone in female cases



The above **Tab-16 and Fig-16** represents the summary of mean width of the body of the hyoid bone along with standard deviation for various age groups in the female cases**.** The mean width of the body of the hyoid bone along with standard deviation for all the age groups in female cases were calculated and entered. The mean width of the body of the age group 18-25 years was found to be 1.84±0.17 cm, the mean width of the body of the age group 26-32 years was 1.82±0.15 cm, the mean width of the body of the age group 33 to 39 years was 1.84±0.13 cm, the mean width of the body of the age group 40-46 years was 1.75±0.16 cm, the mean width of the body of the age group 47-53 years was 1.89±0.07 cm, the mean width of the body of the age group 54-60 years was 1.82±0.17 cm. The mean width of the body of hyoid bone of the entire female cases was 1.82±0.15 cm.

Results of statistical analysis:

The mean, standard deviation and standard error for all the five parameters for both the male and female hyoid bones was calculated and tabulated in the following tables:

Table 17- Average maximal cornual length

	Mean (in cm)	**Standard deviation (in cm)**	**Standard error (in cm)**
Male	3.22	0.25	0.0235
Female	2.69	0.27	0.0390

Table 18-Width of the hyoid bone:

	Mean (in cm)	**Standard deviation (in cm)**	**Standard error (in cm)**
Male	3.75	0.32	0.0288
Female	2.97	0.29	0.0317

Table 19- Length of the hyoid bone

	Mean (in cm)	**Standard deviation (in cm)**	**Standard error (in cm)**
Male	3.90	0.23	0.0215
Female	3.30	0.25	0.0342

Table 20- Vertical height of the body:

	Mean (in cm)	Standard deviation (in cm)	Standard error (in cm)
Male	1.11	0.10	0.0094
Female	0.96	0.13	0.0201

Table 21 - Transverse width of the body:

	Mean (in cm)	Standard deviation (in cm)	Standard error (in cm)
Male	2.13	0.28	0.0256
Female	1.82	0.15	0.0229

Table 22

Consolidated Table showing the Mean and Standard Deviation for Each of the five parameters for Male and Female Bones:

	Average Maximal Cornual Length (in cm)	**Width of hyoid bone (in cm)**	**Length of hyoid bone (in cm)**	**Vertical height of the body of hyoid bone (in cm)**	**Transverse width of the body of hyoid bone (in cm)**
Male Hyoid Bones	3.22±0.25	3.75±0.32	3.90±0.23	1.11±0.10	2.13±0.28
Female Hyoid Bones	2.69± 0.27	2.97±0.29	3.30±0.25	0.96±0.13	1.82±0.15

Table- 23

Multivariant Model for Discriminant Analysis to find out which Parameter is most dimorphic

This discriminant analysis has been done to find which of the above five parameters shows greater sexual dimorphism.

Variables in the Analysis							
		Wilks' Lambda	**Approx. Sig. P.value**	**Rao's Value**	**Approx. Sig. P.value**	**Change in Value**	**Approx. Sig. P.value**
1	**Width of the hyoid bone**	.394	.000	305.110	.000	305.110	0.000
2	**Width of the hyoid bone**	.280	.000	509.410	.000	204.299	0.000
	Length of the hyoid bone						
3	**Width of the hyoid bone**	.260	.000	563.669	.000	54.259	0.000
	Length of the hyoid bone						
	Width of the body of the hyoid bone						
4	**Width of the hyoid bone**	.250	.000	592.885	.000	29.216	0.000
	Length of the hyoid bone						
	Width of the body of the hyoid bone						
	Height of the body of the hyoid bone						

From the above table, it was concluded that the width of the hyoid bone is the most dimorphic parameter (highest for wilks lambda and least value for Rao's value). It is also concluded that, all the the P.values are 0.000 (<0.05) which is significant. The above analysis also proves that, when the number of parameters of the hyoid bone used in determining the sex increases, the accuracy level also increases and there is more chances estimating the sex with accuracy.

Table- 24 Tests of equality of group means:

	Wilks' Lambda	**F**	**Significance P value**
AVERAGE MAXIMAL CORNUAL LENGTH	.502	196.169	.000
WIDTH OF THE HYOID BONE	.394	305.110	.000
LENGTH OF THE HYOIDBONE	.403	293.495	.000
HEIGHT OF THE BODY OF HYOID BONE	.691	88.588	.000
WIDTH OF THE BODY OF THE HYOID BONE	.711	80.489	.000

Test Results

Box's M		68.319
F	Approx.	4.424
	df1	15
	df2	114830.947
	Sig.	.000(<0.05)

From the above table we conclude that, the BOX'S M value is significant 0.000(<0.05) and thus null hypothesis is rejected and significant differences exist between the means of the five parameters. The width of the hyoid bone shows marked sexual dimorphism, second most dimorphic parameter was the length of the hyoid bone, third most dimorphic parameter was average mean cornual length , followed by height of the body of the hyoid bone and finally the transverse width of the body of the hyoid bone.

Table-25 Discriminant functions for determining sex from the hyoid bone

Coefficients[a]							
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
(Constant)	5.563	.191		29.143	.000	5.187	5.940
WIDTH OF THE HYOID BONE	-.402	.051	-.402	-7.884	.000	-.503	-.302
LENGTH OF THE HYOID BONE	-.468	.067	-.365	-6.989	.000	-.601	-.336
WIDTH OF THE BODY OF THE HYOID BONE	-.262	.072	-.150	-3.618	.000	-.405	-.119
HEIGHT OF THE BODY OF HYOID BONE	-.503	.187	-.122	-2.686	.008	-.873	-.134
a. Dependent Variable: SEX							

The above table denotes the coefficient values for various parameters for both sexes. all the result values are significant (<0.05)

Discriminant Score for determining sex from the hyoid bone

Function Number	Discriminant function score	Cut off point	Total function accuracy	Accuracy of sexes
1	D=(-0.402)(W1)+ (-0.468)(L)+ (-0.262)(W2)+ (-0.503)(H)+C	0.0865	80.2%	M:84.2% F:80.6%

Where,

D is the Discriminant score

W1 is the width of the hyoid bone

L is the length of the hyoid bone

W2 is the transverse width of the body of hyoid bone

H is the height of the body of hyoid bone

C is the constant-5.563

The above table denotes the discriminant score obtained from the discriminant analysis of the functions. On substituting the formula with the values of the parameters that were obtained from each hyoid bones, we can estimate the sex of the individual. If the result comes 1, then the sex of the bone is male. If the result comes 2, then the sex is female.

Analysis of Variance (ANOVA) for Difference between the Various Age Groups (The purpose of this study was to test if there is a significant Difference between the various age groups for a given parameter)

Table 26- Average Maximal cornual length of the hyoid bone – Males

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.Value
Between Groups	5	1.090	0.218	3.690	0.004
Within Groups	114	6.737	0.059		
Total	119	7.827			

In the above test, the P value is 0.004, which is significant (<0.05). **Hence there is significant difference in the mean cornual length among various age groups in the male cases.**

Table- 27 Average maximal cornual length of the hyoid bone – Females

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.81	0.016	0.213	0.956
Within Groups	74	5.641	0.076		
Total	79	5.722			

In the above test, the P value is 0.956, which is not significant (>0.05). Hence there is no significant difference in the mean cornual length among various age groups in the female cases.

Table-28 Width of the hyoid bone – Males

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.492	0.098	0.963	0.444
Within Groups	114	11.645	0.102		
Total	119	12.137			

In the above test, the P value is 0.444, which is not significant (>0.05). Hence there is no significant difference in the mean width of the hyoid bone among various age groups in the male cases.

Table-29 Width of the hyoid bone – Females

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.292	0.058	0.670	0.647
Within Groups	74	6.451	0.087		
Total	79	6.744			

In the above test, the P value is 0.647, which is not significant (>0.05). Hence there is no significant difference in the mean width of the hyoid bone among various age groups in the female cases.

Table-30 Length of the hyoid bone – Males

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.353	0.071	1.301	0.269
Within Groups	114	6.186	0.054		
Total	119	6.539			

In the above test, the P value is 0.269, which is not significant (>0.05). Hence there is no significant difference in the mean length of the hyoid bone among various age groups in the male cases.

Table- 31 Length of the hyoid bone – Females

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.515	0.103	1.638	0.161
Within Groups	74	4.655	0.063		
Total	79	5.171			

In the above test, the P value is 0.161, which is not significant (>0.05). Hence there is no significant difference in the mean length of the hyoid bone among various age groups in the female cases.

Table-32 Vertical Height of the body of the hyoid bone – Males

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.066	0.013	1.270	0.239
Within Groups	114	1.177	0.010		
Total	119	1.243			

In the above test, the P value is 0.239, which is not significant (>0.05). Hence there is no significant difference in the mean vertical height of the body of the hyoid bone among various age groups in the male cases.

Table-33 Vertical Height of the body of the hyoid bone – Females

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.050	0.010	0.573	0.716
Within Groups	74	1.280	0.017		
Total	79	1.329			

In the above test, the P value is 0.716, which is not significant (>0.05). Hence there is no significant difference in the mean vertical height of the body of the hyoid bone among various age groups in the female cases.

Table-34 Transverse width of the body of the hyoid bone – Males

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.422	0.084	1.093	0.368
Within Groups	114	8.797	0.077		
Total	119	9.218			

In the above test, the P value is 0.368, which is not significant (>0.05). Hence there is no significant difference in the mean Transverse width of the body of the hyoid bone among various age groups in the male cases.

Table-35 Transverse width of the body of the hyoid bone – Females

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F. Ratio	P.value
Between Groups	5	0.097	0.019	0.790	0.560
Within Groups	74	1.816	0.025		
Total	79	1.913			

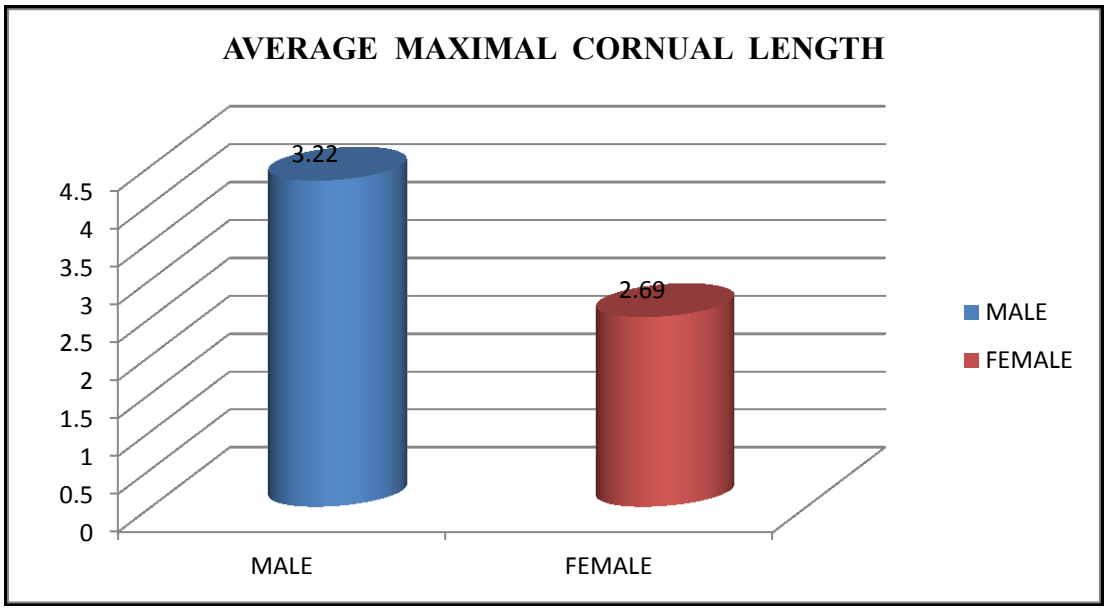
In the above test, the P value is 0.560, which is not significant (>0.05). Hence there is no significant difference in the mean Transverse width of the body of the hyoid bone among various age groups in the female cases.

Independent Samples Test

Independent "t" test was done to compare the parameters between male and female groups.

Table-36 Average maximal cornual length

SEX		N	Mean	Std. Deviation	Std. Error Mean	T value	P value
MEAN CORNUAL LENGTH	MALE	120	3.2281	0.25646	0.02341	14.006	P<0.0001
	FEMALE	80	2.6953	0.26913	0.03009		

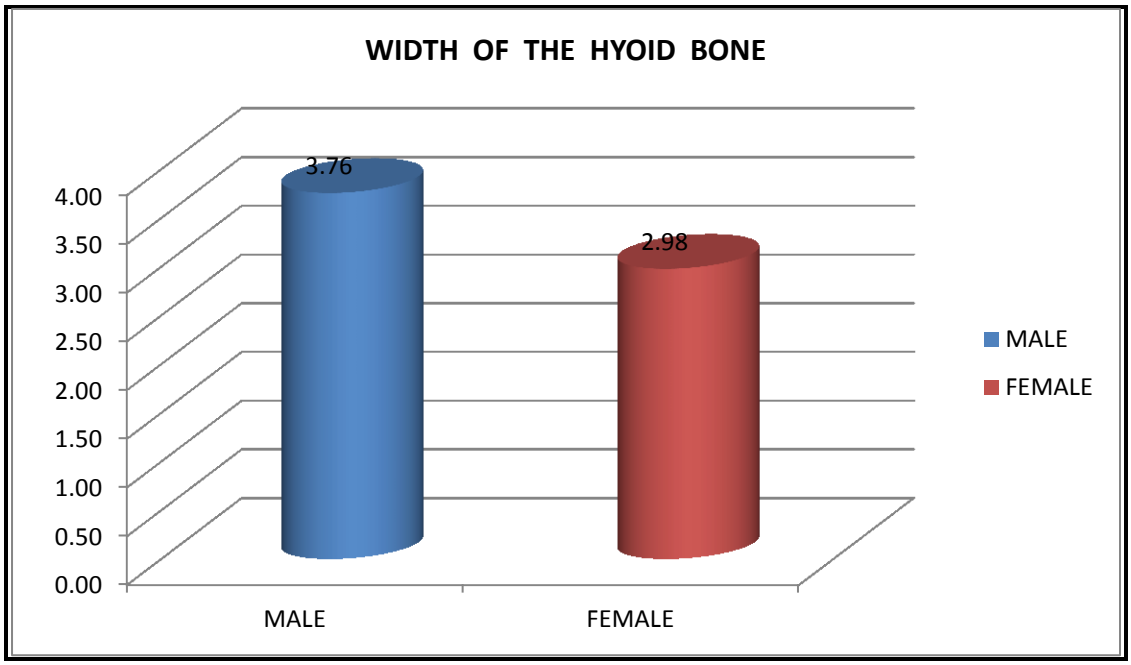


Above table and graph represents the independent "t" test done to compare the mean cornual length of the hyoid bone between males and females. There were significant differences in the mean cornual length of the hyoid bone between male and female groups

Table-37 Width of the hyoid bone

Independent sample test

SEX		N	Mean	Std. Deviation	Std. Error Mean	T value	P value
WIDTH OF THE HYOID BONE	MALE	120	3.7564	0.31936	0.02915	17.467	P<0.0001
	FEMALE	80	2.9739	0.29217	0.03267		

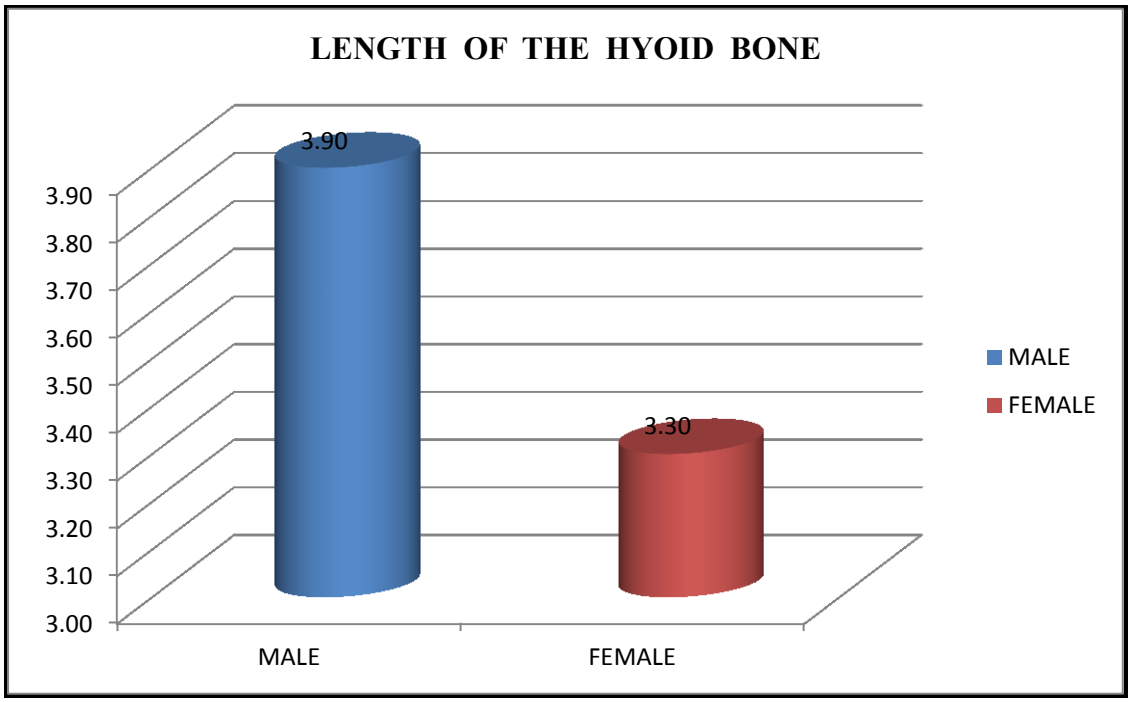


Above table and graph represents the independent "t" test done to compare the mean width of the hyoid bone between males and females. There were significant differences in the mean width of the hyoid bone between male and female groups

Table-38 length of the hyoid bone

Independent sample test

SEX		N	Mean	Std. Deviation	Std. Error Mean	T value	P value
LENGTH OF THE HYOID BONE	MALE	120	3.9043	0.23441	.02140	17.132	P<0.0001
	FEMALE	80	3.3030	0.25584	.02860		

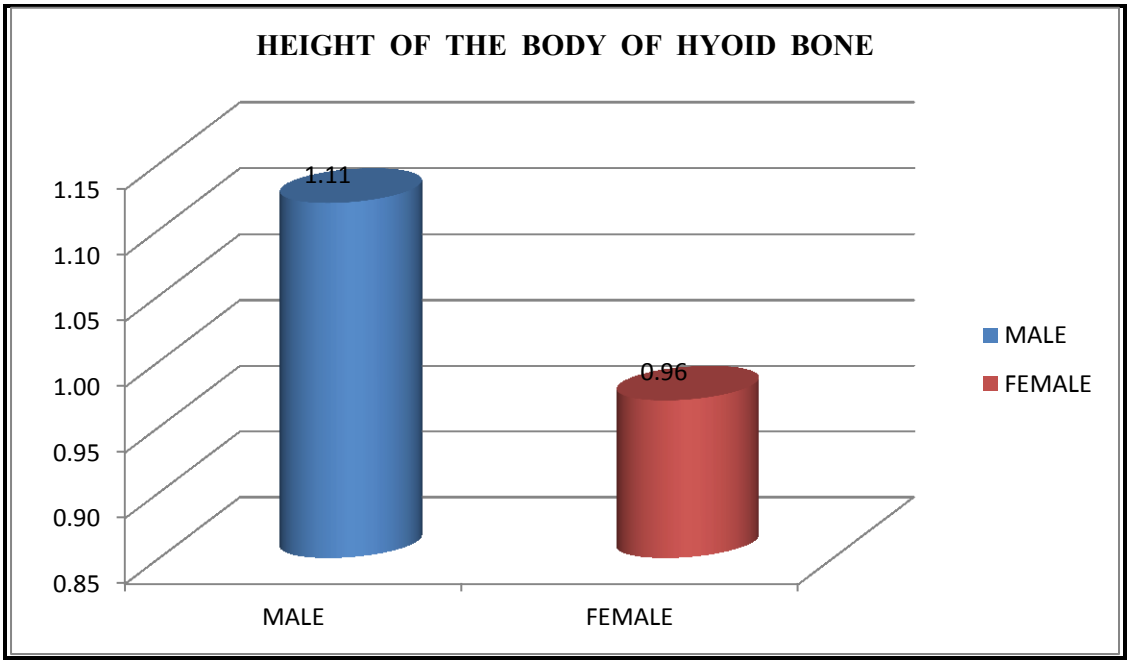


Above table and graph represents the independent "t" test done to compare the mean length of the hyoid bone between males and females. There were significant differences in the mean length of the hyoid bone between male and female groups

Table-39 Vertical length of the body of the hyoid bone

Independent Samples Test

SEX		N	Mean	Std. Deviation	Std. Error Mean	T value	P value
HEIGHT OF THE BODY OF HYOID BONE	MALE	120	1.1183	0.10172	0.00929	10.690	P<0.0001
	FEMALE	80	0.9625	0.08432	0.00943		

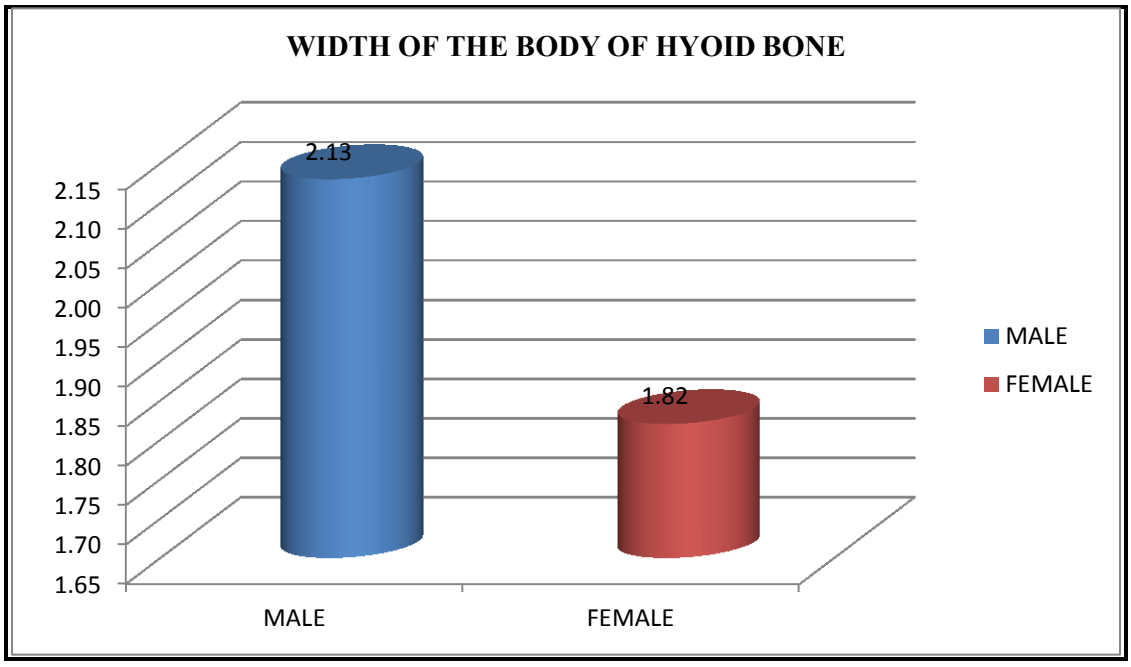


Above table and graph represents the independent "t" test done to compare the mean height of the body of the hyoid bone between males and females. There were significant differences in the mean height of the body of the hyoid bone between male and female groups

Table-40 Transverse width of the body of the hyoid bone

Independent Samples Test

SEX		N	Mean	Std. Deviation	Std. Error Mean	T value	P value
	FEMALE	80	0.9725	0.08432	0.00943		
WIDTH OF THE BODY OF THE HYOID BONE	MALE	120	2.1329	0.27833	0.02541	8.972	P<0.0001
	FEMALE	80	1.8259	0.15563	0.01740		



Above table and graph represents the independent "t" test done to compare the mean Transverse width of the body of the hyoid bone between males and females. There were significant differences in the mean transverse width of the body of the hyoid bone between male and female groups

DISCUSSION

In this study we analysed the sexual dimorphism in the hyoid bone using five parameters namely- the mean cornual length, the width of the hyoid bone, the length of the hyoid bone, the height of the body of the hyoid bone and the transverse width of the body of the hyoid bone. The final interpretation has been done with the following points in consideration:

- Is there a significant sexual dimorphism in the hyoid bone?
- Which is the best parameter proving significant sexual dimorphism in the hyoid bone?
- What is the relationship between dimorphism and age?
- How do the various results obtained from our study compare with the results of other studies?

SEXUAL DIMORPHISM AMONG VARIOUS PARAMETERS

The following are the detailed analysis of the results obtained from the morphometric measurements of the hyoid bones (Table- 17 to Tab- 22)

1. **Average maximal cornual length of the hyoid bone**

The mean cornual length of the hyoid bone for the males was found to be 3.22±0.25 cm. The mean cornual length of the hyoid bone for female bone was found to be 2.69±0.27 cm. For the male bones, the average cornual length was found to range from 2.76 cm to 4.11 cm, additionally 98% of the male bones were found to be greater than 2.79 cm in length. For female bones, the average cornual length was found to range from 2.23 cm to 3.34 cm, additionally in 98% of female bones it was found to be less than 3.19 cm in length. It could thus be inferred that bones with length greater than 3.34 cm could only be male, while bones with length lesser than 2.76cm could only be female.

2. **Width of the hyoid bone**

The mean width of the hyoid bone for males was found to be 3.75±0.32 cm. The mean width of the hyoid bone for females was found to be 2.97±0.29 cm. For male bones the average width was found to range from 2.18 cm to 4.42 cm, additionally in 98% of the male bones width was found to be greater than 3.15 cm in width. For female bones, the average width was found to range from 2.10 cm to 3.47 cm, additionally in 98% of female bones width was found to be less than 3.34 cm. Thus it could be inferred that bones with width greater than 3.47

cm could only be male, while bones with width lesser than 2.18cm could only be females.

3. **Length of the hyoid bone**

The mean length of the hyoid bone for males was found to be 3.90±0.23 cm. The mean length of the hyoid bone for females was found to be 3.30±0.25 cm. For male bones the average length was found to range from 3.40 cm to 4.55 cm, additionally in 98% of the male bones length was found to be greater than 3.50 cm in length. For female bones, the average length was found to range from 2.85 cm to 3.77 cm; additionally in 98% of female bones length was found to be less than 3.72 cm. Thus it could be inferred that bones with length greater than 3.77 cm could only be male, while bones with length lesser than 3.40 cm could only be females.

4. **Vertical height of the body of the hyoid bone**

The mean height of the body of the hyoid bone for males was found to be 1.11±0.10 cm. The mean height of the body of the hyoid bone for females was found to be 0.96±0.13 cm. For male hyoid bones, the average height was found to range from 0.89 cm to 1.38 cm, additionally in 98% of the male bones it was found to be greater than 0.96 in height. For female bones, the average height was found to range from 0.81 cm to 1.12 cm, additionally in 98% of the female bones it was found to be less than 1.08 cm in height. It could thus be inferred that bones with height greater than 1.12 cm could only be male, while bones with height less than 0.89cm could only be females

5. **Transverse width of the body of the hyoid bone**

The mean transverse width of the body of the hyoid bone for males was 2.13±0.28 cm. The mean transverse width of the body of the hyoid bone for females was 1.82±0.15 cm. For male bones, the width of the body of the hyoid bone was found to range from 1.20 cm to 3.03 cm; additionally in 98% of male bones, the width was found to be greater than 1.81 cm. For female bones, the width of the body of the hyoid bone was found to range from 1.55 cm to 2.21 cm, additionally in 98% of female bones width was found to be less than 2.10 cm. It could thus be inferred that bones with width greater than 2.21 cm could only be male, but bones with width less than 1.55 cm could also be male, since the lowest measurement value for the width of the body of the male hyoid bone (1.20 cm) is lesser than the female bone (1.55 cm)

Thus we were able to demonstrate a significant sexual dimorphism in the hyoid bone with regard to all the five parameters. From the above analysis models it was determined that sexual dimorphism is most marked in the width of the hyoid bone, followed by the length of the hyoid bone, followed by the average maximal cornual length, next the vertical height of the body of the hyoid bone and finally in the transverse width of the body of the hyoid bone.

RELATIONSHIP OF SEXUAL DIMORPHISM WITH AGE

1. 18-25 years :

The mean cornual length of the hyoid bone for males was found to be 3.28±0.23 cm. The mean cornual length of the hyoid bone for females was found to be 2.70±0.30 cm. The mean width of the hyoid bone for males was found to be 3.76±0.27 cm. The mean width of the hyoid bone for females was found to be 3.04±0.28 cm. The mean length of hyoid bone for males was found to be 3.94±0.21 cm. The mean length of hyoid bone for females was found to be 3.34±0.25 cm. The mean height of the body of the hyoid bone for males was found to be 1.14±0.09 cm. The mean height of the body of the hyoid bone for females was found to be 0.93±0.19 cm. The mean width of the body of the hyoid bone for males was found to be 2.13±0.30 cm. The mean width of the body of the hyoid bones for females was found to be 1.84±0.17 cm.

2. **26- 32 years:**

The mean cornual length of the hyoid bone for males was found to be 3.32±0.28 cm. The mean cornual length of the hyoid bone for females was found to be 2.70±0.30 cm. The mean width of the hyoid bone for males was found to be 3.82±0.25 cm. The mean width of the hyoid bone for females was found to be 3.00±0.20 cm. The mean length of hyoid bone for males was found to be 3.85±0.20 cm. The mean length of hyoid bone for females was found to be 3.33±0.16 cm. The mean height of the body of the hyoid bone for males was found to be 1.12±0.11 cm. The mean height of the body of the hyoid bone for

females was found to be 0.97±0.08 cm. The mean width of the body of the hyoid bone for males was found to be 2.18±0.34 cm. The mean width of the body of the hyoid bones for females was found to be 1.82±0.15 cm.

3. 33-39 years:

The mean cornual length of the hyoid bone for males was found to be 3.16±0.21 cm. The mean cornual length of the hyoid bone for females was found to be 2.64±0.15 cm. The mean width of the hyoid bone for males was found to be 3.71±0.25 cm. The mean width of the hyoid bone for females was found to be 2.95±0.21 cm. The mean length of hyoid bone for males was found to be 3.95±0.26 cm. The mean length of hyoid bone for females was found to be 3.28±0.24 cm. The mean height of the body of the hyoid bone for males was found to be 1.10±0.11 cm. The mean height of the body of the hyoid bone for females was found to be 0.97±0.08 cm. The mean width of the body of the hyoid bone for males was found to be 2.16±0.20 cm. The mean width of the body of the hyoid bones for females was found to be 1.84±0.13 cm.

4. 40-46 years:

The mean cornual length of the hyoid bone for males was found to be 3.30±0.29 cm. The mean cornual length of the hyoid bone for females was found to be 2.67±0.23 cm. The mean width of the hyoid bone for males was found to be 3.83±0.50 cm. The mean width of the hyoid bone for females was found to be 2.89±0.31 cm. The mean length of hyoid bone for males was found to be 3.80±0.22 cm. The mean length of hyoid bone for females was found to

be 3.14±0.23 cm. The mean height of the body of the hyoid bone for males was found to be 1.13±0.10 cm. The mean height of the body of the hyoid bone for females was found to be 0.95±0.06 cm. The mean width of the body of the hyoid bone for males was found to be 2.18 ±0.23 cm. The mean width of the body of the hyoid bones for females was found to be 1.75±0.16 cm.

5. 47-53 years:

The mean cornual length of the hyoid bone for males was found to be 3.10±0.19 cm. The mean cornual length of the hyoid bone for females was found to be 2.77±0.27 cm. The mean width of the hyoid bone for males was found to be 3.77±0.40 cm. The mean width of the hyoid bone for females was found to be 3.02±0.23 cm. The mean length of hyoid bone for males was found to be 3.92±0.27 cm. The mean length of hyoid bone for females was found to be 3.29±0.24 cm. The mean height of the body of the hyoid bone for males was found to be 1.10±0.10 cm. The mean height of the body of the hyoid bone for females was found to be 1.01±0.09 cm. The mean width of the body of the hyoid bone for males was found to be 2.07±0.12 cm. The mean width of the body of the hyoid bones for females was found to be 1.89±0.07 cm.

6. 53-60 years:

The mean cornual length of the hyoid bone for males was found to be 3.12±0.21 cm .The mean cornual length of the hyoid bone for females was found to be 2.71±0.32 cm. The mean width of the hyoid bone for males was found to be 3.61±0.32 cm. The mean width of the hyoid bone for females was

found to be 2.90±0.44 cm. The mean length of hyoid bone for males was found to be 3.93±0.27 cm. The mean length of hyoid bone for females was found to be 3.40±0.32 cm. The mean height of the body of the hyoid bone for males was found to be 1.08±0.10 cm. The mean height of the body of the hyoid bone for females was found to be 0.99±0.06 cm. The mean width of the body of the hyoid bone for males was found to be 2.05±0.32 cm. The mean width of the body of the hyoid bones for females was found to be 1.82±0.17 cm.

TABLE- 41 COMPARISON OF RESULTS IN THIS STUDY WITH THAT OF PRIYA ET. AL STUDY

Parameter	Male	Male	Female	Female
	Priya et.al	Present study	Priya et.al	Present Study
Mean Cornual Length (in cm)	3.24±0.23	3.22±0.25	2.84±0.23	2.69±0.27
Width of the Hyoid (in cm)	3.90±0.81	3.75±0.32	3.22±0.60	2.97±0.29
Length of the Hyoid (in cm)	3.65±0.27	3.90±0.23	3.19±0.27	3.30±0.25
Height of the Body of the Hyoid (in cm)	1.18±0.15	1.11±0.10	1.00±0.10	0.96±0.13
Width of the Body of the Hyoid (in cm)	2.32±0.30	2.13±0.28	2.00±0.14	1.82±0.15

In the above table, our study results are compared with that of Priya et. al study(26) results. The mean cornual length of male cases in our study group was 3.22±0.25 cm and in female cases it was 2.69±0.27cm, the difference being ststistically significant (p.value<0.001). In both the above studies compared, all the parameters are greater in male cases than in the female cases. The present study is correlating with the Priya et.al study(26), the difference being statistically significant (P.Value <0.001)

TABLE-42 COMPARISON OF RESULTS IN THIS STUDY WITH THAT OF HARJEET AND JIT I STUDY(25)

Parameter	Male	Male	Female	Female
	Harjeet study	Present study	Harjeet study	Present Study
Mean Cornual Length (in cm)	3.37±0.28	3.22±0.25	2.97±0.27	2.69±0.27
Width of the Hyoid (in cm)	3.72±0.58	3.75±0.32	3.18±0.47	2.97±0.29
Length of the Hyoid (in cm)	3.86±0.32	3.90±0.23	3.40±0.28	3.30±0.25
Height of the Body of the Hyoid (in cm)	1.10±0.27	1.11±0.10	0.94±0.10	0.96±0.13
Width of the Body of the Hyoid (in cm)	2.40±0.23	2.13±0.28	2.02±0.15	1.82±0.15

In the above table, our study parameters are compared with that of Harjeet and Jit I study(25) parameters. The length of the hyoid bone in the male cases of our study was 3.90±0.23cm and in females it was 3.30±0.25 cm, the difference being satistically significant (p value<0.001). The male hyoid bones are larger than female hyoid bones in all the parameters, the present study is similar to Harjeet and Jit I study(25) , the difference being statistically significant(p value<0.001).

TABLES-43 COMPARISON OF RESULTS IN THIS STUDY WITH THAT OF AMRUTHA ET. AL

Parameter	Male	Male	Female	Female
	Amrutha study	Present study	Amrutha study	Present study
Mean Cornual Length (in cm)	3.20±0.25	3.22±0.25	2.87±0.24	2.69±0.27
Width of the Hyoid (in cm)	3.72±0.77	3.75±0.32	3.27±0.56	2.97±0.29
Length of the Hyoid (in cm)	3.68±0.31	3.90±0.23	3.23±0.24	3.30±0.25
Height of the Body of the Hyoid (in cm)	1.18±0.15	1.11±0.10	1.00±0.17	0.96±0.13
Width of the Body of the Hyoid (in cm)	2.26±0.31	2.13±0.28	2.03±0.15	1.82±0.15

In the above table, our study results are compared with that of Amrutha et. al study results(12). The height of the body of the hyoid bones in the male cases of our study was 1.11±0.10 cm and in females it was 0.96± 0.13 cm, the difference being statistically significant (p value<0.001). In both the above studies compared, all the parameters are greater in male cases than in the female cases. The present study is correlating with the Amrutha et.al study(12), the difference being statistically significant (P.Value <0.001)

COMPARISON OF RESULTS IN THIS STUDY WITH THAT OF MILLER ET.AL(28):

1. In our study we found that the average maximum cornual lengths were 3.22 cm for males and 2.69 cm for females. By comparison the corresponding values reported by miller et al. were 2.83 cm for males, 2.74 cm for females.
2. In our study we found that the vertical height of the hyoid bone at its midpoint perpendicular to the bone surface was 1.11cm for males versus 0.96 cm for females. By comparison the corresponding values reported by miller et al.(28) were 0.79 cm for males and 0.74 cm for females.
3. In our study we found that the transverse width of the body of the hyoid bone was 2.13 cm for males and 1.82 cm for females. By comparison the corresponding values reported by miller et al.(28) were 2.14 cm for males and 1.98 cm for females.

TABLE-43 MILLER ET. AL STUDY(28)

	Average maximum Cornual length (in cm)	**Average vertical height of the body of the hyoid bone (in cm)**	**Average transverse width of the body of the hyoid bone (in cm)**
Male Hyoid Bones	2.83	0.79	2.14
Female Hyoid Bones	2.74	0.74	1.98

CONCLUSION

1. There is a definite sexual dimorphism in the hyoid bone and it was demonstrated in this study using the five parameters. There is a clear cut demarcation between the values of male and female bone. The sexual dimorphism is most marked in the width of the hyoid bone, followed by the length of the hyoid bone, next in the average mean cornual length , followed by height of the body of the hyoid bone and finally in the transverse width of the body of hyoid bone. The dimorphism is constant across the age spectrum for all the parameters, except the Average maximal cornual length in male cases where there is significant difference seen among various age groups.
2. The present study is correlating with other similar studies done on the sexual dimorphism of the hyoid bone. There is a greater sexual dimorphism observed in our study compared to the study done by miller et al. (28), since the study groups were different in both the studies. Miller et al.(28) study was conducted in the American population, who belong to the Caucasian race. Here the study was done exclusively in the south Indian population. Hence there is a relatively greater sexual dimorphism for hyoid bone in south Indian study sample than for the Caucasians.
3. Hence, it is possible to determine the sex of the hyoid bone using various parameters obtained in our study, given a situation where a hyoid bone of an unknown person is found .When more than one

parameter is used, it is possible to determine the sex of the individual to a reasonable degree of accuracy. In such cases, the width of the hyoid bone should be used as one of the parameters along with other measurements as the sexual dimorphism is more marked in this parameter.

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PROFORMA

PM no:

Date:

Name:

Age:

Sex:

Length of Rt greater Cornu:

Length of Lt greater Cornu:

Average maximal cornual length:

Width of the hyoid bone:

Length of the hyoid bone:

Width of the body of hyoid bone:

Length of the body of hyoid bone:

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
1	40	Female	MMC	2.91	2.1	3.55	1.02	1.81
2	25	male	MMC	3.94	3	4.55	1.38	3.03
3	40	male	MMC	3.23	2.18	3.66	1.12	1.85
4	30	female	MMC	2.36	2.98	3.57	0.86	1.62
5	18	female	MMC	2.47	2.84	2.85	0.92	1.96
6	23	male	MMC	3.38	3.55	3.93	1.18	2.09
7	60	female	MMC	2.83	2.95	3.77	0.98	1.66
8	48	male	MMC	3.06	4.2	3.97	1.16	2.11
9	39	male	MMC	3.81	3.43	4.22	1.37	1.86
10	34	male	MMC	3.12	3.85	3.63	1.01	2.02
11	35	male	MMC	3.16	3.77	4.12	1.11	1.92
12	30	female	MMC	2.62	2.79	3.4	1	1.7
13	60	Female	MMC	2.52	2.3	3.16	0.92	1.62
14	35	male	MMC	3.2	3.84	4.42	1.09	2.32
15	60	Female	MMC	2.78	2.25	3.64	0.95	1.95
16	22	male	MMC	3.38	3.65	4.18	1.13	2.35
17	60	Female	MMC	3	3.79	3.73	1.08	2.12
18	24	male	MMC	3.09	3.46	4	1.1	1.91
19	47	Female	MMC	2.92	2.61	3.39	1.02	1.99
20	25	Female	MMC	2.85	3.74	3.34	1.04	1.9
21	18	Male	MMC	3.36	3.09	3.88	1.14	2.11
22	25	female	MMC	2.98	3.44	3.18	1.08	1.91
23	38	male	MMC	3.34	3.78	4.25	0.94	1.89
24	20	male	MMC	2.9	3.34	3.85	1.24	1.92
25	42	male	MMC	3.2	4.23	3.46	1	2
26	49	male	MMC	3.12	3.61	4.11	1.15	1.89
27	18	Female	MMC	2.61	2.63	2.95	0.86	1.79
28	56	male	MMC	3.37	3.41	3.92	1.08	1.81
29	43	Female	MMC	2.71	3.1	2.99	0.91	2
30	28	male	MMC	3.2	3.78	4.06	1.25	2.72

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
31	30	male	MMC	3.46	3.73	3.4	1.13	2.52
32	45	male	MMC	3.09	3.79	3.94	1.16	2.43
33	35	male	MMC	3.24	3.84	3.96	0.98	2.32
34	57	male	MMC	3.52	3.96	4.2	1.15	2.72
35	60	male	MMC	3.19	4.14	3.55	1.27	1.81
36	60	Female	MMC	3.19	2.85	3.3	1.06	1.87
37	28	male	MMC	3.28	3.8	3.56	1.22	1.2
38	45	male	MMC	4.11	4.44	3.87	1.32	2
39	45	male	MMC	3.28	3.77	3.61	1.15	1.95
40	48	Female	MMC	2.8	2.9	2.92	0.9	1.82
41	40	Female	MMC	2.65	2.89	2.88	0.94	1.72
42	43	male	MMC	3.27	4.12	3.78	1.06	2.09
43	28	female	MMC	2.78	2.76	3.09	0.88	1.63
44	55	female	MMC	2.54	2.63	2.95	1.02	1.92
45	44	male	MMC	3.58	3.88	3.55	1.19	2.52
46	26	female	MMC	2.89	3.01	3.2	1.05	2.01
47	52	male	MMC	2.94	4.06	3.67	1.14	2.14
48	23	male	MMC	3.06	3.94	3.84	1.22	2.22
49	19	male	MMC	3.19	3.87	3.67	1.16	1.99
50	49	female	MMC	3.14	3.18	3.44	1.1	1.96
51	48	male	MMC	3.22	4.58	3.72	1.19	2.04
52	31	male	MMC	3.45	3.57	3.95	1.32	2.16
53	53	male	MMC	3.41	3.32	4.51	1.15	1.94
54	28	male	MMC	3.64	4.21	3.91	1.05	1.89
55	46	female	MMC	2.6	3.13	2.89	0.94	1.69
56	33	male	MMC	3.15	3.28	4.2	1.2	2.57
57	60	female	MMC	2.82	3.47	3.67	1.03	1.6
58	50	male	MMC	2.89	3.8	4.07	1.16	2.32
59	38	male	MMC	2.79	3.15	4.14	1.23	2.22
60	36	female	MMC	2.78	2.84	3.56	0.86	1.9

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
61	18	male	MMC	3.17	3.3	3.81	1.14	1.99
62	30	female	MMC	2.54	2.66	3.29	1.01	2.02
63	19	female	MMC	2.41	2.56	3.43	1.01	2.21
64	55	male	MMC	3.14	3.96	4.12	1	1.95
65	55	male	MMC	2.76	3.29	4.31	0.95	1.98
66	58	male	MMC	2.88	3.36	3.82	1.07	2.29
67	22	male	MMC	3.29	3.78	3.67	1.12	1.2
68	25	male	MMC	3.92	4.26	4.23	1.29	2.12
69	19	male	MMC	3.17	3.45	3.95	1.1	2.16
70	38	male	MMC	3.33	4.02	3.62	1.16	2.31
71	47	Female	MMC	2.54	3.15	3.12	1.06	1.86
72	26	male	MMC	2.99	3.54	3.59	1.08	2.04
73	60	male	MMC	3.02	3.34	4.04	1.14	1.98
74	55	Female	MMC	2.52	2.67	2.85	1.02	1.64
75	42	female	MMC	2.26	2.6	3.07	0.89	1.57
76	24	male	MMC	3.56	4.16	4.23	1.23	2.11
77	49	male	MMC	2.78	3.43	3.78	0.9	1.95
78	30	male	MMC	3.63	4.13	3.88	1.11	2.77
79	55	male	MMC	2.94	3.23	4.25	1.02	1.84
80	36	female	MMC	2.5	2.86	3.19	0.98	1.74
81	55	male	MMC	3.16	3.75	3.72	1.08	2
82	49	male	MMC	2.81	3.6	3.66	0.96	2.14
83	45	male	MMC	3.75	4.24	3.79	1.34	2.34
84	36	male	MMC	3.31	3.78	4.12	1.14	2.07
85	21	male	MMC	3.29	3.61	3.92	1.12	2.52
86	60	male	MMC	2.89	3.18	3.48	0.89	2.1
87	47	Female	MMC	2.86	3.09	3.6	1.1	1.92
88	23	male	MMC	3.67	4	3.62	1.3	2.6
89	35	male	MMC	2.98	3.49	3.42	1.05	1.92
90	22	male	MMC	3.29	3.72	3.7	1.19	2.3

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
91	18	female	MMC	2.39	2.79	3.53	1.05	1.76
92	38	Female	MMC	2.89	3.23	3.57	1.11	1.78
93	33	male	MMC	3.11	3.9	4.15	1.14	1.98
94	45	male	MMC	3.02	3.84	3.64	1.04	2.18
95	29	male	MMC	3.46	3.98	3.83	1.18	2.11
96	22	female	MMC	2.58	2.9	2.98	0.81	1.6
97	26	female	MMC	2.76	3	3.25	0.93	1.9
98	19	female	MMC	3.1	3.26	3.66	0.88	2
99	40	female	MMC	2.92	3.17	3.3	1	1.66
100	28	male	MMC	3.35	4.04	3.77	1.12	1.96
101	24	female	MMC	2.46	2.99	3.16	0.82	1.82
102	19	female	MMC	2.87	3.2	3.32	1.06	1.69
103	35	male	MMC	3.23	3.87	4.12	1.04	2.11
104	39	male	MMC	3.21	4	3.93	1.07	2.23
105	49	male	MMC	2.92	3.48	3.72	1.14	2.01
106	58	male	MMC	3.37	3.99	4.22	1.23	1.22
107	52	female	MMC	2.37	3.19	3.25	0.89	1.82
108	59	female	MMC	3.18	2.89	3.11	1.02	1.74
109	31	male	MMC	3.54	3.94	3.78	1.16	2.43
110	22	male	MMC	3.17	3.87	3.97	1.1	2
111	30	female	MMC	3.34	3.23	3.48	1.1	1.69
112	19	female	MMC	2.54	2.77	3.07	1.03	1.95
113	48	male	MMC	2.97	3.68	3.98	0.96	1.99
114	29	male	MMC	3.89	4.42	4.15	1.25	2.33
115	23	male	MMC	3.25	3.87	3.75	1.09	2.03
116	19	male	MMC	3	4	3.46	1.13	1.94
117	18	female	MMC	2.6	3.29	3.56	0.83	1.58
118	60	female	MMC	2.23	3.16	3.67	0.86	2.01
119	42	male	MMC	3.24	3.88	4.18	1.12	2.09
120	44	female	MMC	2.77	3.09	3.33	0.94	1.62

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
121	20	female	MMC	2.76	3.34	3.72	0.99	1.59
122	25	male	MMC	3.14	3.56	3.62	1.1	2.22
123	31	male	MMC	3.46	3.92	4.16	1.18	2.24
124	39	Female	MMC	2.7	2.89	2.98	0.95	1.72
125	33	male	MMC	3.11	3.3	3.5	1.26	1.95
126	44	male	MMC	3.22	3.86	3.9	1.12	2.05
127	46	male	MMC	3.25	3.89	3.96	1.2	2.07
128	59	male	MMC	3.26	3.76	3.86	1.1	2.16
129	60	male	MMC	3.14	3.54	3.65	1.02	2.04
130	25	female	MMC	3.09	3.23	3.57	1.06	1.75
131	60	Female	MMC	2.24	3	3.59	1	1.87
132	24	male	MMC	3.08	3.9	3.96	1.09	1.95
133	32	Female	MMC	2.6	3.18	3.5	0.94	1.92
134	59	Female	MMC	2.73	2.85	3.33	1.01	1.86
135	54	male	MMC	3.09	3.75	3.87	1.07	2.11
136	35	Female	MMC	2.49	2.67	3.27	1	1.8
137	29	male	MMC	2.76	3.42	3.61	0.9	2.31
138	18	male	MMC	3.18	3.74	3.88	1.15	1.95
139	41	Female	MMC	2.88	2.72	3	1.06	1.82
140	39	Female	MMC	2.49	2.95	3.29	1.03	1.74
141	29	male	MMC	3.26	3.83	3.95	1.18	2.01
142	22	male	MMC	3.38	4.06	4.17	1.2	1.99
143	28	female	MMC	2.58	3.29	3.46	0.96	1.92
144	36	female	MMC	2.57	2.76	2.92	0.89	2.05
145	18	female	MMC	3.32	3.14	3.56	1.1	1.72
146	42	female	MMC	2.26	3.29	3.52	0.9	1.68
147	35	male	MMC	3.2	3.86	3.94	1.08	2.46
148	39	male	MMC	3.16	3.63	3.87	1.1	2.12
149	26	male	MMC	2.77	3.41	3.63	0.9	2.34
150	28	male	MMC	3.65	3.75	3.98	1.27	2.61

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
151	19	female	MMC	2.79	2.93	3.28	1.02	2
152	31	female	MMC	3.01	2.89	3.11	1.08	1.74
153	42	female	MMC	2.81	2.83	2.89	0.96	1.7
154	44	male	MMC	3.15	3.99	4.11	1.1	1.96
155	24	female	MMC	3.14	3.27	3.67	1.01	1.84
156	30	male	MMC	3.22	3.72	3.89	1.04	2.31
157	41	male	MMC	2.89	3.58	3.63	1	2.3
158	25	male	MMC	3.32	3.81	3.96	1.13	2.23
159	38	female	MMC	2.48	3.24	3.56	0.87	1.96
160	33	male	MMC	3	3.78	3.84	1.11	2.25
161	22	female	MMC	2.97	3.13	3.29	1.04	1.6
162	29	male	MMC	3.21	3.7	3.92	1.08	2.18
163	40	male	MMC	3.39	4.05	4.12	1.12	2.54
164	38	female	MMC	2.77	3.26	3.43	0.97	2.02
165	18	male	MMC	3.08	3.82	4.01	0.92	2.43
166	31	Female	MMC	2.29	3.15	3.32	0.86	1.92
167	46	male	MMC	3.23	3.56	3.62	1.11	2.53
168	33	male	MMC	2.78	3.64	3.75	0.89	2.32
169	20	female	MMC	2.89	2.97	3.15	1.04	1.82
170	25	male	MMC	3.61	3.77	3.93	1.12	2.32
171	39	Female	MMC	2.75	2.89	3.07	1.04	1.69
172	46	Female	MMC	2.42	2.86	3.19	0.89	1.6
173	29	male	MMC	2.98	3.55	3.67	0.94	2.15
174	23	Female	MMC	2.34	3.08	3.6	0.85	1.99
175	35	male	MMC	3.11	4.02	3.99	1.08	2.27
176	27	male	MMC	3.39	3.94	4.08	1.12	2.1
177	20	female	MMC	3.11	3.39	3.73	1.12	1.93
178	25	male	MMC	3.39	3.74	3.88	1.28	2.29
179	28	male	MMC	3.32	3.86	3.98	1.19	1.8
180	34	male	MMC	2.99	3.69	3.74	1.04	2.2

S.NO	AGE	SEX	INSTITUTE	AVERAGE MEAN CORNUAL LENGTH	WIDTH OF THE HYOID BONE	LENGTH OF THE HYOID BONE	HEIGHT OF THE BODY OF HYOID BONE	WIDTH OF THE BODY OF THE HYOID BONE
181	46	female	MMC	2.93	3.03	3.17	1.01	1.88
182	42	female	MMC	2.59	2.81	3	1.06	2.1
183	22	female	MMC	2.37	2.67	3.29	0.99	1.67
184	19	male	MMC	3.28	3.98	4.02	1.13	1.69
185	25	male	MMC	3.17	3.83	3.92	1.04	2.57
186	24	female	MMC	2.78	3.11	3.66	1	1.9
187	32	male	MMC	3.09	3.79	3.89	1.08	1.91
188	25	male	MMC	2.95	3.86	3.91	0.98	1.83
189	18	male	MMC	3.19	4	4.15	1.1	2.01
190	19	female	MMC	2.57	2.87	3.1	0.87	1.55
191	25	male	MMC	3.41	3.9	4.06	1.17	2.35
192	18	female	MMC	2.49	2.64	3.06	0.84	1.96
193	22	male	MMC	3.14	3.81	3.97	1.1	2.09
194	24	male	MMC	3.22	3.98	4.12	1.13	2.44
195	19	female	MMC	2.83	3.18	3.42	0.77	1.91
196	25	female	MMC	2.27	2.88	3.22	0.89	2
197	23	male	MMC	3.32	3.75	3.86	1.23	2
198	21	male	MMC	3.07	3.88	4.01	1.02	1.97
199	18	female	MMC	2.25	2.91	3.11	0.91	2.12
200	18	male	MMC	3.28	3.79	4.29	1.1	2.19

Urkund Analysis Result

Analysed Document: Determination of Sex From Hyoid Bone new update.docx (D42604019)
Submitted: 10/16/2018 5:52:00 AM
Submitted By: suganchander89@gmail.com
Significance: 6 %

Sources included in the report:

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