MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND IT'S CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION

Thesis submitted for the award of the degree of
Doctor of Philosophy in Medical Anatomy

By

Mr. Anandagouda. V. Naikanur
Registration No: 17PHD001

Department of Anatomy

under the guidance of
Dr. B. M. Bannur

and co-guidance of
Dr. Sanjeev. I. Kolagi

BLDE

(Deemed to be University)
Shri B. M. Patil Medical College, Hospital & Research Centre,
Vijayapur-586103, Karnataka, India

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Shri B. M. Patil Medical College, Hospital and Research Centre,
Vijayapura - 586103

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I declare that the thesis entitled **"Multidetector Computed Tomographic morphology of Olfactory Fossa and its correlation with Body Mass Index in North Karnataka Region"** submitted by me for the degree of Doctor of Philosophy (PhD) is the record of work carried out by me under the guidance of **Dr. B. M. Bannur**, Professor of Anatomy, BLDE's (Deemed to be University) Shri B. M. Patil Medical college, Hospital and Research Centre, Vijayapura, Karnataka and **Dr. Sanjeev. I. Kolagi**, Professor and HOD of Anatomy, S. Nijalingappa Medical College, Bagalkot, Karnataka, and has not formed the basis for the award of any degree, diploma, associateship, fellowship, titles in this university or other similar institution of higher learning.

Date:
Place: Vijayapura.

Signature of the candidate
Mr. Anandagouda V Naikanur
Registration No: 17PHD001
Department of Anatomy,
BLDE (Deemed to be University)'s
Shri B. M. Patil Medical College,
Hospital & Research Centre,
Vijayapura, Karnataka

BLDE
(Deemed to be University)
Shri B. M. Patil Medical College, Hospital and Research Centre,
Vijayapura - 586103

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This is to certify that the thesis entitled **"Multidetector Computed Tomographic Morphology of Olfactory Fossa and its correlation with Body Mass Index in North Karnataka Region"** submitted for the degree of Doctor of Philosophy (PhD) by **Mr. Anandagouda. V. Naikanur** is the record of research work carried out by him under my supervision and guidance and that this has not formed the basis for the award of any degree, diploma, associateship, fellowship, titles in this university or other similar institution of higher learning.

Signature of the Guide
Dr. B. M. Bannur
Professor of Anatomy,
Department of Anatomy,
BLDE (Deemed to be University)'s
Shri B. M. Patil Medical College,
Hospital & Research Centre,
Vijayapura, Karnataka

Date:
Place: Vijayapura.

BLDE
(Deemed to be University)
Shri B. M. Patil Medical College, Hospital and Research Centre,
Vijayapura - 586103

CERTIFICATE FROM THE CO-GUIDE

This is to certify that the thesis entitled **"Multidetector Computed Tomographic morphology of Olfactory Fossa and its correlation with Body Mass Index in North Karnataka Region"** submitted for the degree of Doctor of Philosophy (PhD) by **Mr. Anandagouda. V. Naikanur** is the record of research work carried out by him under my supervision and guidance and that this has not formed the basis for the award of any degree, diploma, associateship, fellowship, titles in this university or other similar institution of higher learning.

Signature of the Co-guide
Dr. Sanjeev. I. Kolagi
Professor and Head,
Department of, Anatomy
S. Nijalingappa Medical College,
Bagalkot,Karnataka

Date:
Place: Vijayapura

BLDE
(Deemed to be University)
Shri B. M. Patil Medical College, Hospital and Research Centre,
Vijayapura - 586103

CERTIFICATE FROM THE HEAD OF THE INSTITUTION AND THE DEPARTMENT

This is to certify that the thesis entitled **"Multidetector Computed Tomographic morphology of Olfactory Fossa and its correlation with Body Mass Index in North Karnataka Region"** submitted for the degree of Doctor of Philosophy (PhD) is the record of research work carried out by **Mr. Anandagouda.V.Naikanur** under the guidance and supervision of **Dr. B. M. Bannur**, Professor of Anatomy, BLDE (Deemed to be University)'s Shri B. M. Patil Medical college, Hospital and Research Centre, Vijayapura, Karnataka; and **Dr. Sanjeev. I. Kolagi**, Professor and HOD of Anatomy, S. Nijalingappa Medical College, Bagalkot, Karnataka; in partial fulfillment for the award of Doctor of Philosophy in the faculty of Medicine and that this work was carried out by him in the Department of Anatomy.

Signature of the HOD
Dr. R. S. Bulagouda
Professor & Head,
Department of Anatomy,
BLDE (Deemed to be University)'s
Shri B. M. Patil Medical College,
Hospital & Research Centre,
Vijayapura, Karnataka

Signature of the Principal
Dr. Aravind Patil
Principal,
BLDE (Deemed to be University)'s
Shri B. M. Patil Medical College,
Hospital & Research Centre,
Vijayapura, Karnataka

I dedicate this research work to my Family and Friends

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LIST OF ABBREVIATIONS

Abbreviations	Full form
CP	Cribriform plate
CG	Crista galli
LLCP	Lateral lamella of cribriform plate
OF	Olfactory fossa
LL	Lateral lamella
ACF	Anterior cranial fossa
EAC	Ethmoidal air cell
OR	Orbit
MT	Middle turbinate
NS	Nasal septum
LP	Lamina papyracea
FE	Fovea ethmoidalis
FESS	Functional endoscopic sinus surgeries
BMI	Body mass index
WHO	World health organization
NASH	Non alcoholic steatohepatitis
IIH	Idiopathic intracranial hypertension
SCSF	Spontaneous cerebrospinal fluid
CSF	Cerebrospinal fluid
OFD	Olfactory fossa depth
MDCT	Multidetector computed tomography

NC	Neural crest
OE	Olfactory epithelium
CT	Computed tomography
FE	Fovea ethmoidalis
PNS	Paranasal air sinuses
MERP	Medial ethmoidal roof point
N	Number
Ht	Height
R	Right
L	Left

ABSTRACT

Multidetector computed tomographic morphology of olfactory fossa and it's correlation with body mass index in North Karnataka region

ABSTRACT

Background: Olfactory fossa is a depression in the anterior cranial cavity which harbours the olfactory nerve and bulb. The depth of olfactory fossa is directly proportional to Body Mass Index. Hence, higher Body Mass Index individuals have deeper olfactory fossa and are most vulnerable to Cerebrospinal fluid leaks during Skull base surgeries and Functional endoscopic sinus surgeries.

Aim: The aim was to study the relationship between depth of the olfactory fossa and Body Mass Index by using Multidetector Computed Tomography in North Karnataka region.

Methods: Paranasal multidetector computed tomographic scans of 820 patients were collected in North Karnataka region, Karnataka, India by using bone window. The depth of olfactory fossa, width, angle of olfactory fossa, thickness of lateral lamella of cribriform plate and length of cribriform plate were estimated on both the sides in both genders. Side symmetry and relation of morphology of olfactory fossa in both genders were calculated by using Student 't' (unpaired) test. Correlation between the depth of olfactory fossa and BMI was calculated by using Pearson's correlation. The data was considered statistically significant if p was less than 0.05.

Results: Type II keros was most common when compared to other types of Keros of olfactory fossa. Statistically significant differences were observed in the depth of olfactory fossa, angulation of olfactory fossa and length of Cribriform plate when compared between male and female patients. Significant differences were not observed in the width of olfactory fossa and thickness of Lateral Lamella of Cribriform Plate when compared between males and female patients. There was a linear correlation between Body Mass Index and Olfactory Fossa depth; as Body Mass Index increases, depth of olfactory fossa shifts from type II to type III.

Conclusion: This would help Radiologists, Neurosurgeons and Endoscopic surgeons to evaluate the complex ethmoidal skull base which are difficult to approach without distortion and without damaging other structures.

Keywords: Olfactory fossa, Body Mass Index, Functional endoscopic sinus surgeries, Cribriform plate, Ethmoidal skull base, Keros type of Olfactory fossa.

INTRODUCTION

CHAPTER 1.

INTRODUCTION

ETHMOID BONE

The cavity of cranial base is divided into anterior, middle and posterior cranial fossa. The floor of the anterior cranial fossa consists of orbital plate of frontal bone on each side and cribriform plate (CP) and crista galli (CG) of ethmoid bone in the middle. The lesser wings and anterior part of the body of the sphenoid forms the posterior boundary of anterior cranial fossa. The anterior cranial fossa lies at the higher level when compared to middle and posterior cranial fossa.[1]

The Ethmoid bone is cuboidal and fragile. It helps in the formation of the roof, medial and lateral walls of the nasal cavity and the medial boundary of the orbit. The parts of the ethmoid bone are cribriform plate, perpendicular plate and two lateral labyrinths as shown in figure 1.

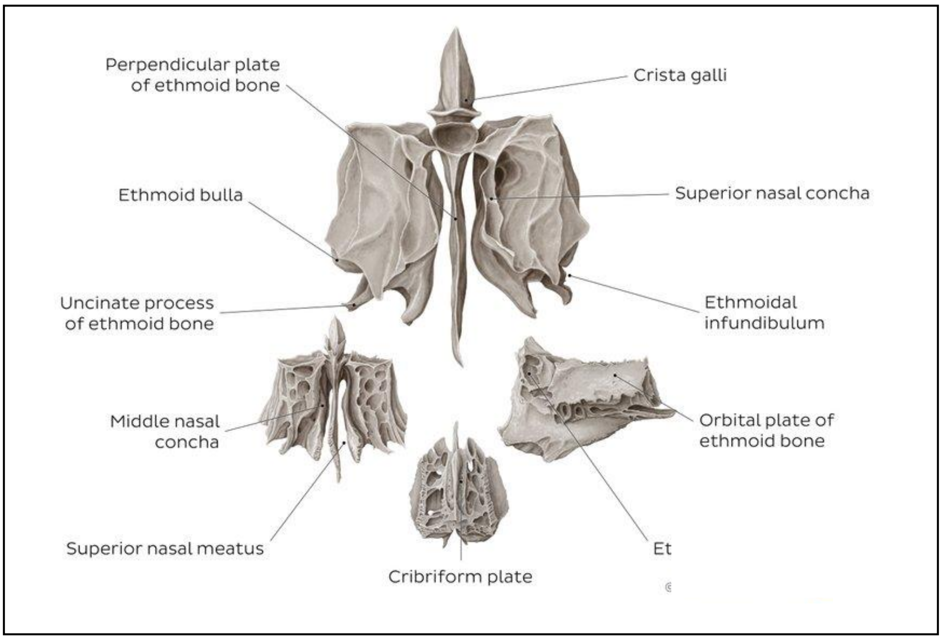

Figure 1: Parts of ethmoid bone

Perpendicular plate of ethmoid bone

It is a quadrilateral bone present in the median plane as shown in figure 2. It is flat, thin bone extends from lower surface of the cribriform plate. Then, it projects downward to form the medial wall of nasal cavity. [1] The anterior part of the perpendicular plate slopes downward and forward and joins with the nasal spine of frontal bone and the crest which inturn formed by the union of two nasal bones. Its posterior border articulates in the lower part of the sphenoidal crest and in the lower part with vomer. Inferior border is grooved to receive the septal cartilage of bone.[2] Anterior or posterior part of the perpendicular plate of ethmoid bone may get pneumatized which leads to deviated nasal septal mucocele. Pneumatization may occur in perpendicular plate of ethmoid in 18% of cases.[3]

Cribriform plate of the ethmoid bone

It is narrow and depressed and covers the ethmoidal notch between the two orbital plates of frontal bone. It is sieve like bone which presents series of apertures on each side. The numerous formania in the cribriform plate of the ethmoid bone helps in transmitting the branches of the olfactory nerve with their arachnoid coverings. This plate has posterior margin, upper and lower surfaces. The upper surface forms the floor of the anterior cranial fossa and presents in the median plane a triangular raised crest, the crista galli. The perforated plate on each side of crista galli supports the gyrus rectus of frontal lobe and the olfactory bulb. The lower surface of crista galli forms the roof of the nasal cavity. The posterior margin joins with the ethmoidal spine of body of sphenoid. [2]

A thick, short triangular process called crista galli projects from the middle of the cribriform plate of ethmoid bone which has broad anterior border compared to its thin curved posterior border as shown in figure 2. Its anterior border joins with the frontal bone by two alae which then forms the foramen caecum. Its posterior border gives attachment to the falx cerebri. Sometimes it's sides show bulges which are related to underlying ethmoidal air cells.[1]

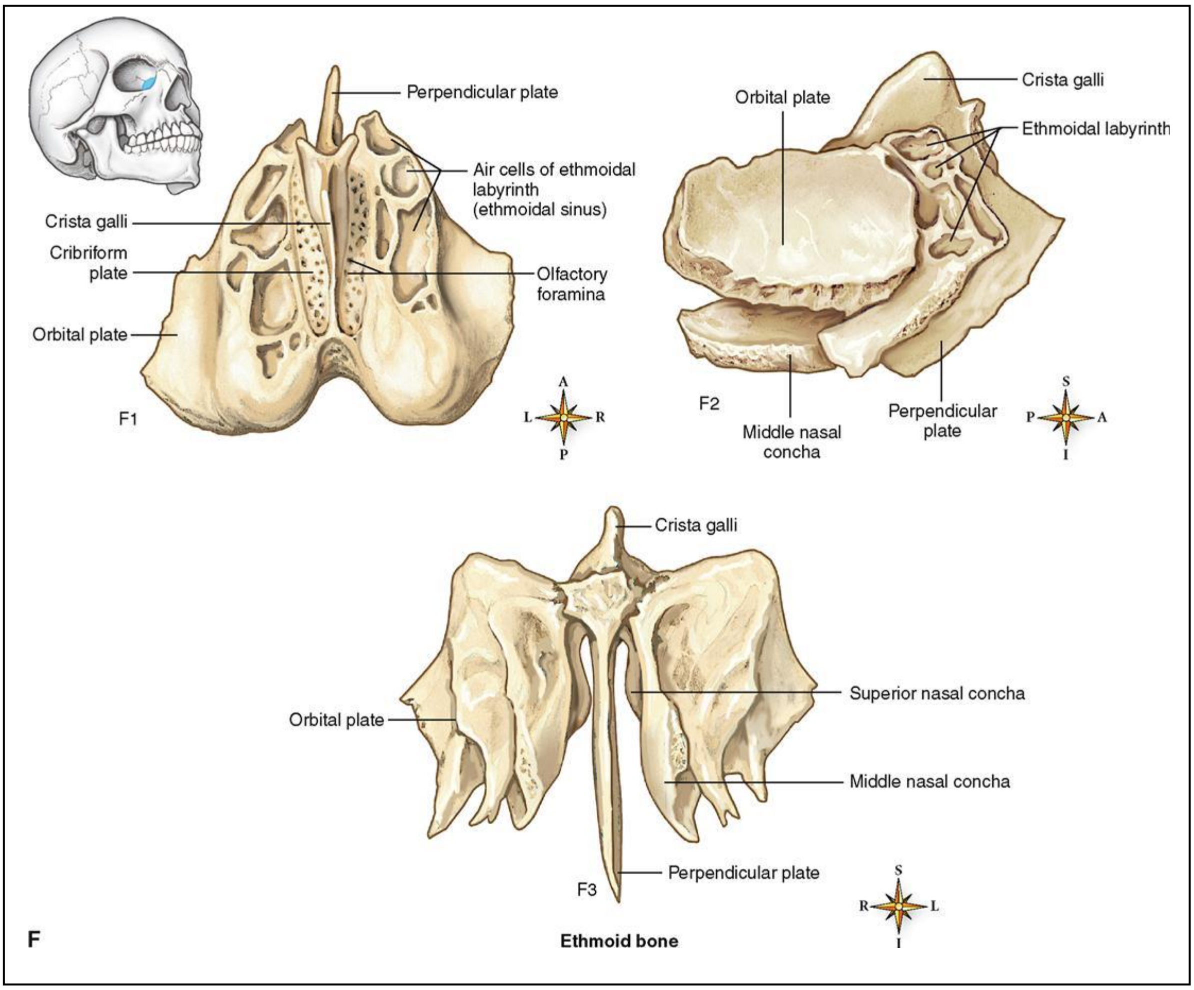

Figure 2: Crista galli and perpendicular plate of ethmoid bone

The anterior ethmoidal nerve enters the cranial cavity in the gap between the cribriform plate of ethmoid bone and orbital plate of the frontal bone. Anteriorly, a small slit lies on either side of the crista galli. A foramen anterolateral to the slit allows the anterior ethmoidal nerve and vessels to the nasal cavity. The posterior ethmoidal canal opening at the posterolateral corner of the cribriform plate transmits the posterior ethmoidal vessels and nerve.[1]

The Ethmoidal labyrinths

Each labyrinth is cuboidal in form. The ethmoidal labyrinths contain ethmoidal air cells. Its lateral surface forms the part of medial wall of orbit. They are located at the junction of the nasal cavity and the orbit.

The superior surface of the labyrinths attaches with the medial margin of the orbital plate of frontal bone. At this junction, anterior and posterior ethmoidal canals transmit the anterior and posterior ethmoidal vessels and nerves respectively. The anterior surface joins with the lacrimal bone and frontal process of the maxilla and completes the anterior ethmoidal sinuses. The posterior surface joins the sphenoidal concha and palatine bone. The lower surface joins with the medial margin of orbital surface of body of the maxilla.

Ethmoidal sinuses

The ethmoidal air cells are present in three groups- anterior, middle and posterior groups. Variations in the diameters of cavities are common on both the sides. There are eleven anterior ethmoidal air cells, three middle ethmoidal air cells and six posterior ethmoid air cells. These ethmoidal sinuses are divided in to anterior and posterior groups clinically. In each category, the ethmoidal sinuses are divided by incomplete bony septa as shown in figure 3. Rapid growth spurt starts from sixth year and after puberty.[1]

The orbital plate of frontal bone overlaps the posterior and middle ethmoidal air cells as shown in figure 3. Nasal plate on the medial surface of labyrinth forms the part of lateral wall of nasal cavity. It ends below as curved plate, the middle nasal concha. Posterior part of the nasal surface above the middle nasal concha presents a narrow oblique groove, superior meatus which is limited above superior nasal concha. The posterior ethmoidal sinuses open in to superior meatus.[2]

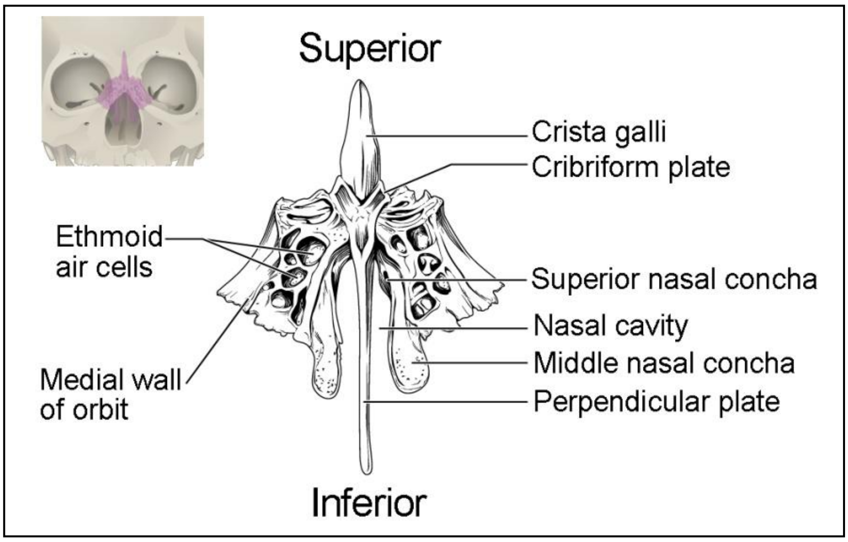

Figure 3: Ethmoid air cells

ETHMOIDAL SKULL BASE

Ethmoidal skull base is the orbital plate of the frontal bone. It extends from upper attachment of lateral lamella of cribriform plate (LLCP) to the junction of the lamina papyracea[4] as shown in figure 4.

Roof of ethmoid bone is the medial extension of orbital plate of frontal bone. It joins with the lateral lamella of cribriform plate medially and ascends laterally as a dome. The cribriform plate of ethmoid is located lower than the ethmoidal roof. Ethmoidal skull base separates the nasal cavity from the olfactory fossa (OF). If ethmoidal roof height is lower, intracranial complications like cerebrospinal fluid fistula and meningitis are common postoperatively.

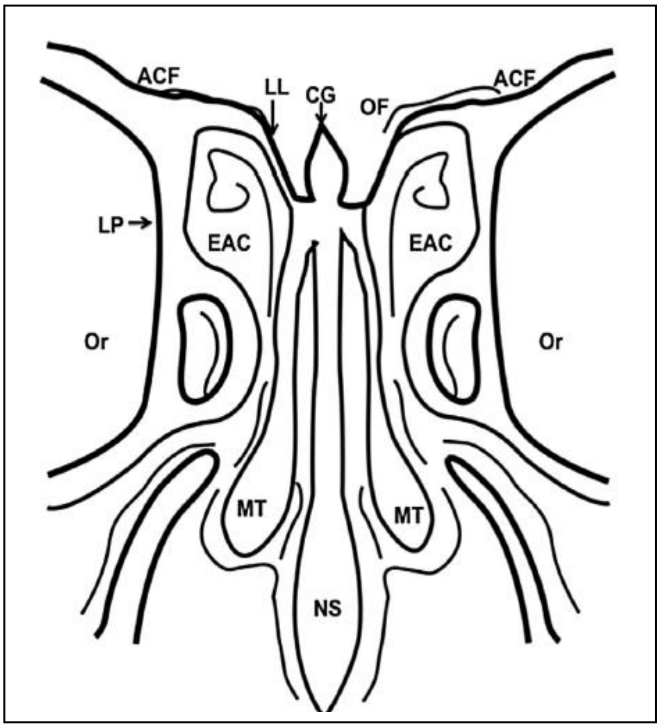

Figure 4: Extension of ethmoidal skull base

OF-Olfactory fossa, CG-crista galli, LL-lateral lamella, ACF-anterior cranial fossa, EAC-ethmoidal air cells, Or-orbit, MT-Middle turbinate, NS-nasal septum, LP-lamina papyracea.

The fovea ethmoidalis (FE) is a part of the frontal bone. It forms the ethmoidal labyrinth roof. It splits the anterior cranial fossa from ethmoidal air cells. The fovea ethmoidalis attaches with the LLCP on its medial side. [5]

Anterior skull base and ethmoid roof asymmetries are important for Endoscopic Sinus Surgeries. If asymmetry is present, there will be variations in the ethmoid roof height. The fovea ethmoidalis may be at different levels. The angle at which the fovea ethmoidalis joins with the cribriform plate determines the shape of the contour of the fovea. If joint angle increases, the shape of fovea ethmoidalis may become straight or broken wing.

Thin LLCP, fovea ethmoidalis and low ethmoidal skull base are at risk during FESS. Complications like direct penetration, trauma to meninges and intracerebral injuries may occur during surgeries.[4] While approaching the anterior ethmoid or frontal recess or when resecting the middle turbinate, the LLCP may be injured in these surgeries. Greater the vertical depth of LLCP, narrower and deeper will be the olfactory fossa and lower will be the roof of the ethmoid bone.

OLFACTORY FOSSA

Olfactory fossa (OF) is a depressed area in the anterior cranial fossa. It is bounded inferiorly by the cribriform plate of the ethmoid bone as shown in figure 5. The cribriform plate is wedged between the orbital plates of frontal bone and extends across the midline. The cribriform plate is depressed between the extended parts of orbital plate of frontal bone. It is the most vulnerable site in whole of the anterior skull base.[1] It harbours the precious olfactory nerve and olfactory bulb which is at danger during Functional Endoscopic Sinus Surgeries. The depth of olfactory fossa is measured by the length of LLCP.[6]

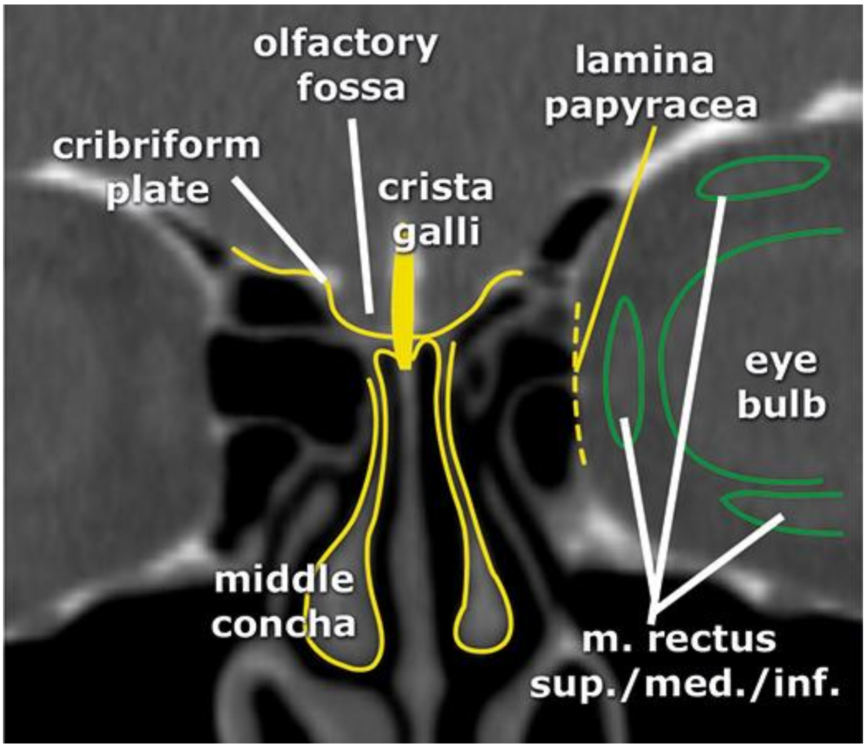

Figure 5: Olfactory fossa

KEROS CLASSIFICATION OF OLFACTORY FOSSA

The relation between olfactory fossa and ethmoidal roof was classified into 3 types by Keros (1962) which is as follows in table no 1.

Table 1: Relation between olfactory fossa and ethmoidal roof

Keros type	Depth of Olfactory fossa	LLCP	Roof of Ethmoid	Incidence in Egyptian population
I	1-3 mm	Short	Ethmoidal roof is in same plane with cribriform plate	26.3%
II	4-7 mm	Long	-	73.3%
III	8-16 mm	-	Ethmoid roof lies significantly above cribriform plate	0.5%

In keros type I of olfactory fossa, the olfactory fossa is 1–3 mm deep and has the short lateral lamella. Frontal bone protects the roof of ethmoid bone and ethmoidal sinuses and making it less dangerous during surgeries. The ethmoidal roof is in same plane with the cribriform plate of ethmoid bone. In the type II olfactory fossa, the olfactory fossa is 4–7 mm deep, and the corresponding lateral lamella forms the portion of the medial ethmoid roof. In the type III olfactory fossa, the olfactory fossa depth is 8–16 mm.The ethmoid roof is present at a significant level above the cribriform plate in type III olfactory fossa[7] as shown in figure 6. The thin lateral lamella forms the important part of the ethmoid roof. Thin LLCP is not protected by the thick frontal bone. As the height of LLCP increases, there will be greater risk of injuries according to Keros.[8] Type III olfactory fossa and thin LLCP are at risk for injuries during surgeries.[6] Keros has also revealed the width of ethmoidal labyrinth and olfactory fossa at different levels and showed that there is a gradual increase in the width of olfactory fossa in the posterior end when compared to the anterior end.[9]

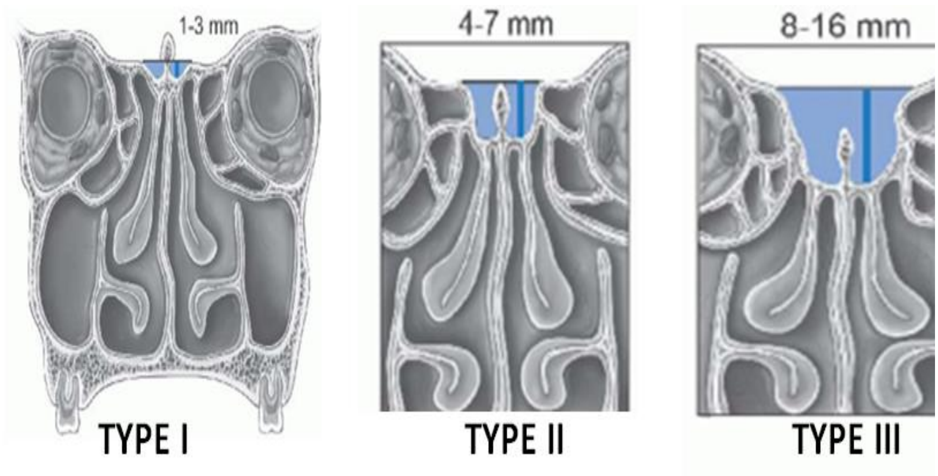

Figure 6: Keros types of olfactory fossa.

Keros type I is common in females (66%), Keros type II is most common in males (48%) and Keros type III was found more commonly in males. LLCP is shorter and oblique in males. The roof of ethmoid was lower in females.[6]

Keros classification of olfactory fossa also guides the surgeons during removal of medial wall of orbit in orbital decompression surgeries. Thus this classification helps in improving the safety profile in these procedures.[10]

OLFACTORY NERVE

The olfactory nerve arises from neurons in olfactory mucosa. Olfactory mucosa is present in the posterior superior part of the lateral nasal wall, part of the middle concha, the opposite part of the nasal septum, the superior concha, the sphenoethmoidal recess, the part of perpendicular plate of the ethmoid and the part of roof of the nose that arches between the septum and lateral wall and lower surface of the cribriform plate. Olfactory mucosa consists of pseudostratified epithelium which contains olfactory receptor neurons, sustentacular cells and basal cells as shown in figure 7. Groups of up to 50 unmyelinated axons from olfactory receptor neurons surrounded by glial cells and meninges pass though the foramina in the cribriform plate of ethmoid bone and enter the anterior cranial fossa as shown in figure 8. Then they synapse in glomeruli with tufted cells and mitral cells in olfactory bulbs.

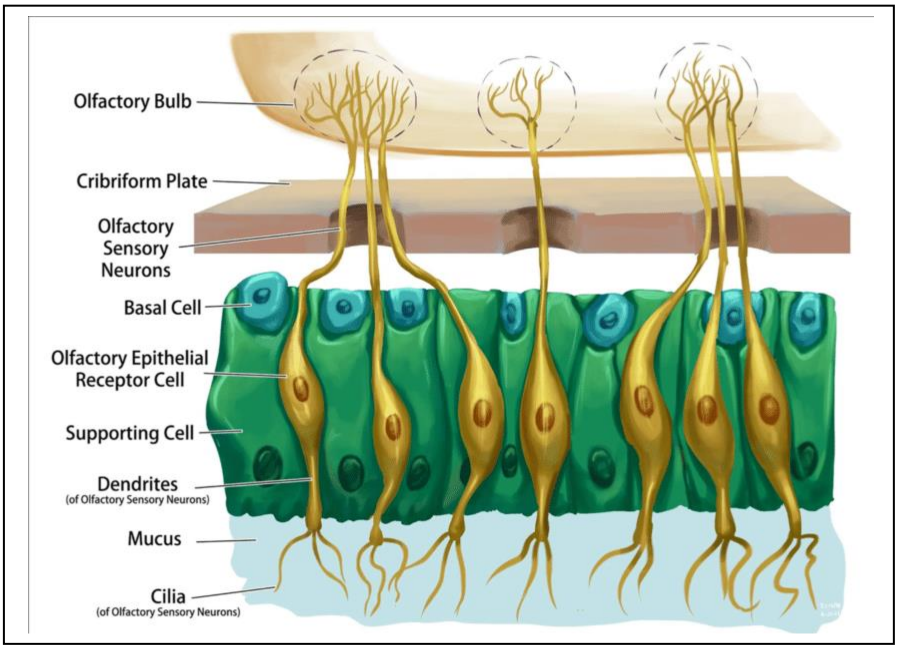

Figure 7: Olfactory neurons

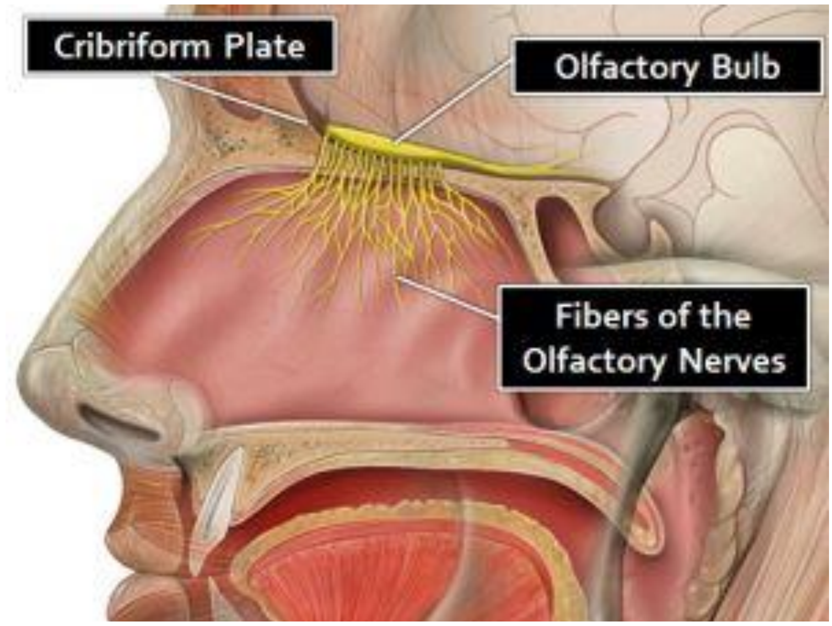

Figure 8: Olfactory nerve

The Laminae in Olfactory bulb contains olfactory nerve layer, glomerular layer, external plexiform layer, mitral cell layer, internal plexiform layer and granule cell layer. The olfactory nerve layer contains unmyelinated axons of the olfactory neurones. The glomerular layer contains glomeruli. Glomeruli are formed when the olfactory axons divide and synapse with tufted, periglomerular and mitral cells. The external plexiform layer has the dendrites of mitral and tufted cells. The mitral cell layer contains the cell bodies of mitral cells and granule cell bodies. Axons, mitral cell, granule cell bodies and mitral cells are present in internal plexiform layer. The granule cell layer consists of majority of granule cells.

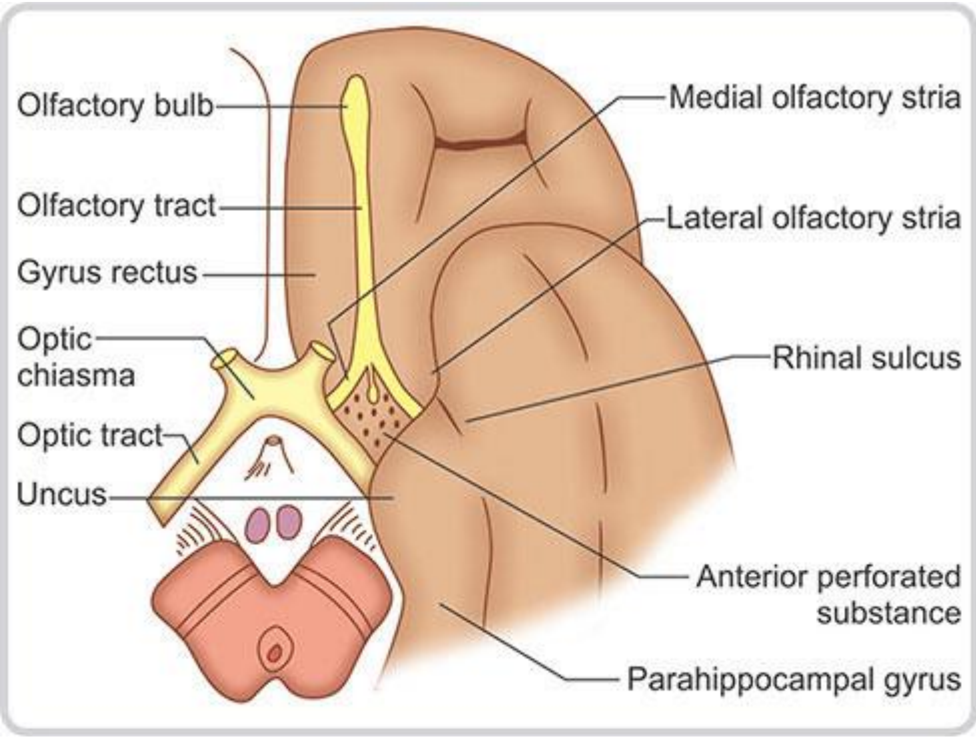

Figure 9: Olfactory bulb and olfactory tract

The axons of mitral and tufted cells form efferent pathways from olfactory bulb. The olfactory tract leaves the the olfactory bulb and passes in the olfactory sulcus on the orbital surface of the frontal lobe as shown in figure 9. The granule cell layer of the bulb is extended into the olfactory tract as scattered medium-sized multipolar neurones which constitute the anterior olfactory nucleus. They extend from the olfactory striae and trigone to the prepiriform cortex, the anterior perforated substance and precommissural septal areas as shown in figure 10. Majority of axons from tufted and mitral cells relay in anterior olfactory nucleus. The anterior olfactory nucleus axons pass along with the fibres from olfactory bulb and then reach the olfactory striae. When olfactory tract reaches the anterior perforated substance, it flattens out and forms the olfactory trigone as shown in figure 11. Olfactory tract fibres diverge as medial and lateral olfactory striae from olfactory trigone as shown in figure 11. Sometimes an intermediate stria travels from olfactory trigone to olfactory tubercle. The lateral olfactory stria joins with gyrus semilunaris at uncus of temporal lobe. The lateral olfactory gyrus forms the grey layer covering the lateral olfactory stria. The lateral olfactory gyrus and gyrus ambiens forms the prepiriform region of cortex. The piriform cortex is formed from the prepiriform region, periamygdaloid regions and the entorhinal area. Thin grey matter of medial olfactory gyrus covers the medial olfactory stria. The medial stria becomes indistinct when it reaches the boundary zone formed by the paraterminal gyrus, parolfactory gyrus and prehippocammpal rudiment.[1]

Abnormalities of olfactory nerve

The abnormalities of the olfactory nerve include the complete disappearance of the olfactory tract and olfactory bulb. It can occur unilaterally or bilaterally in majority of the cases. Among these variations, the bilateral absence of the olfactory bulb and tract was most common variation found in patients with Kallman syndrome.[11 & 12]

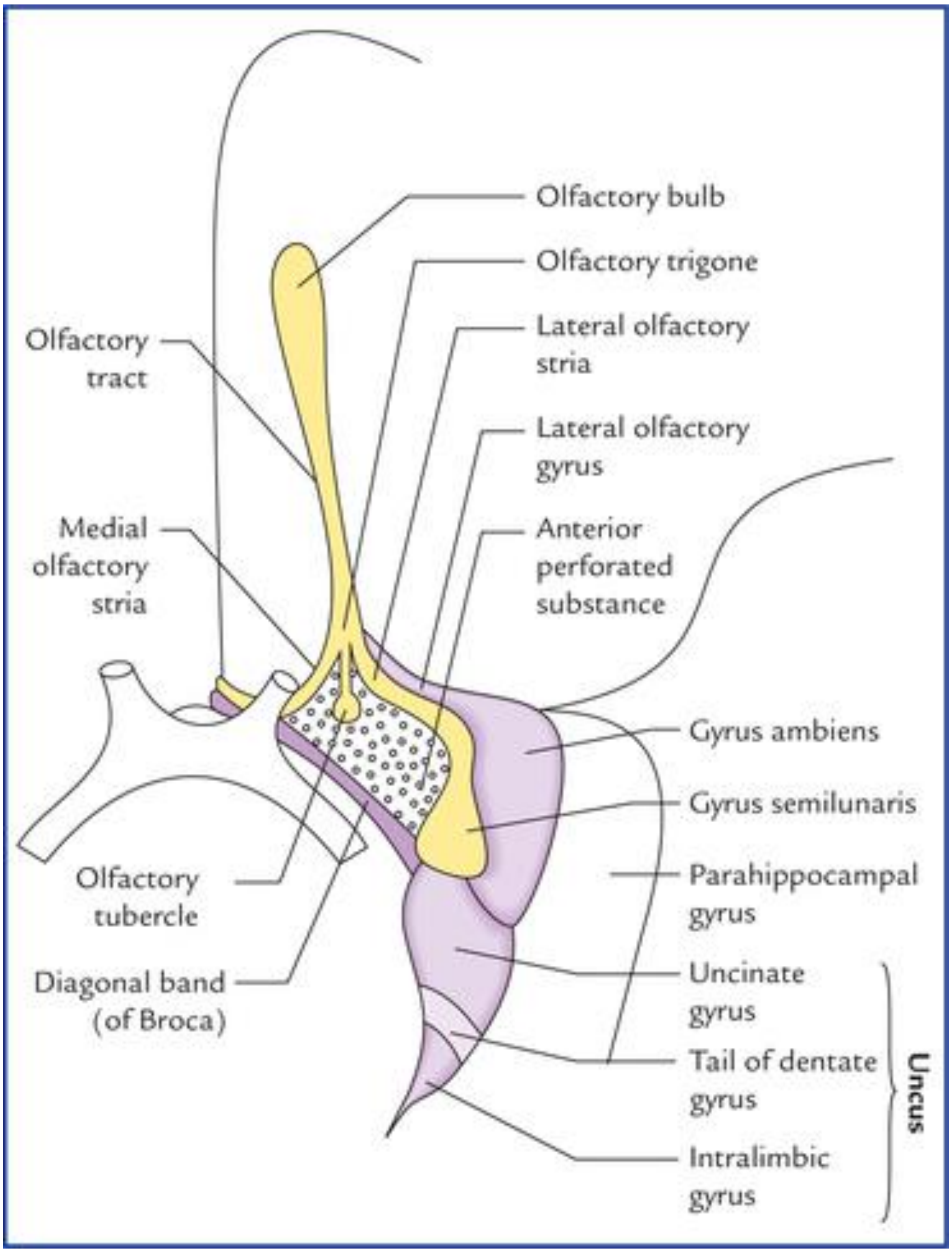

Figure 10: Olfactory trigone

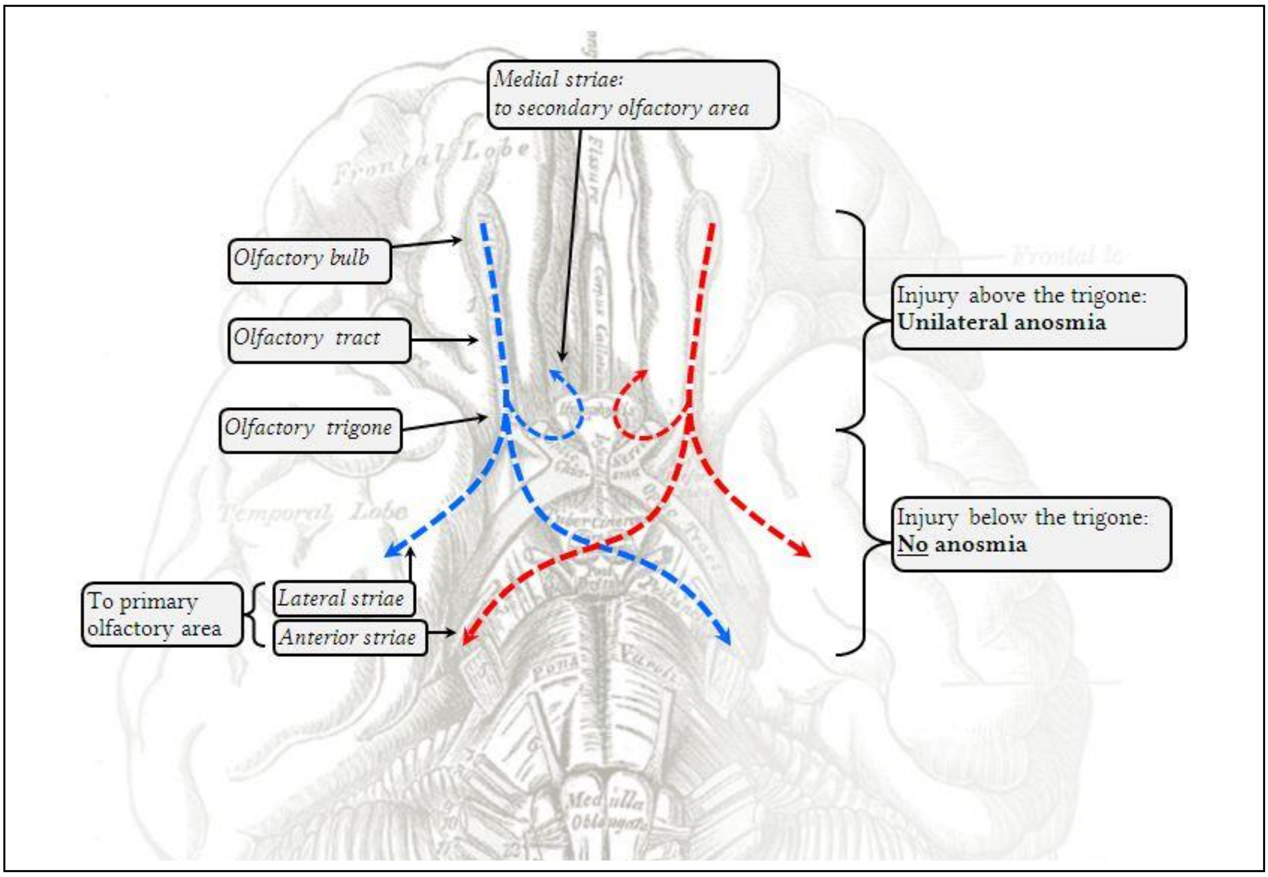

Figure 11: Olfactory striae

BODY MASS INDEX

Body mass index (BMI) is an index of weight-for-height which is commonly used to classify underweight, overweight and obesity in adults. Body mass index is defined as the weight in kilograms divided by the square of the height in metres (kg/m^2).[13] Since 1980, the global obesity rate has nearly doubled. Now there are over 200 million obese males and nearly 300 million obese females.[14] The prevalence of overweight (BMI of 25-30) or obesity (BMI of ≥30) in worlds adult population is predicted to raise from 39% in 2016 to 57.8% in 2030. [15]

Classification of underweight, overweight and obesity according to their BMI according to World Health Organisation (WHO) is shown in table 2. [13]

Table 2: WHO classification of underweight, overweight and obesity.

Classification of BMI	Principal cut-off points (kg/m^2)
Underweight	<18.50
Normal range	18.50 - 24.99
Overweight	≥25.00
Pre-obese	25.00 - 29.99
Obese	≥30.00
Obese class I	30.00 - 34.99
Obese class II	35.00 - 39.99
Obese class III	≥40.00

Classification of underweight, overweight and obesity according to their BMI was done according to WHO guidelines. BMI of underweight patients was less than 18.5. Normal BMI was between 18.5 and 24.9. Greater than 25 BMI was considered as overweight individuals and greater than 30 BMI was considered as obese individuals.[14]

BMI AND COMPLICATIONS

Obesity is associated with a state of chronic low-level inflammation in liver, brain, pancreas and adipose tissue. Hence, obese individuals are at risk to develop infections of surgical-site, urinary tract, nosocomial and skin. The complications of Type 2 diabetes mellitus are dyslipidemia, coronary artery disease, heart failure, stroke, obstructive sleep apnoea, asthma, non-alcoholic steatohepatitis (NASH), cirrhosis, hepatocellular carcinoma, gall bladder disease, hypertension, osteoarthritis, dementia and Alzheimer's disease and impaired renal function as shown in figure 12. Obesity is also related with reduced sperm count and increased rates of erectile dysfunction in men and reduced fertility, poor outcomes after fertility treatment and pregnancy loss in females. Each 5 kg/m2 increase in BMI was is linearly related with cancer of the uterus, gallbladder, kidney, cervix, thyroid and leukaemia.[16]

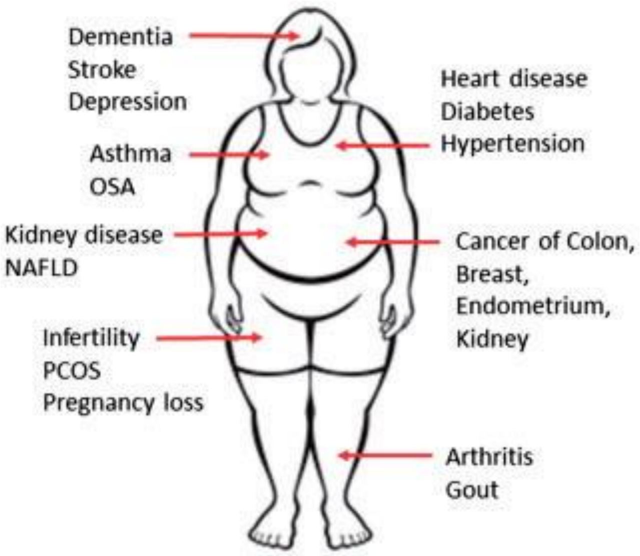

Figure 12: Complications of increase in BMI

BMI, IIH and SCSF

There are reports of body mass index correlating with depth of the olfactory fossa. Elevated body mass index (BMI) is linked to Idiopathic intracranial hypertension (IIH) which in turn linked to spontaneous cerebrospinal fluid (SCSF) leaks.[17]

Patients with idiopathic intracranial hypertension are typically obese female patients presenting with headache, pulsatile tinnitus and visual disturbances.[18] Patients with IIH develop expansion of bone and SCSF leaks in weak areas of cranial base like tegmen tympani and cribriform plate of ethmoid.[17] CSF leaks are very rare but their complications are life threatening. CSF leaks can lead to ascending meningitis or brain abscess. Patients with IIH and SCSF leaks reveal typical characteristic findings like attenuation of skull base and arachnoid pits on CT scans which is not typically present in CSF leaks of other etiologies.[18]

So, there exists a direct relationship between BMI and CSF pressure. Hence, higher BMI individuals are likely to have deeper olfactory fossa and are at risk of spontaneous CSF leaks.

NEED FOR THE STUDY

During Functional Endoscopic Sinus Surgeries (FESS) for a number of diseases like choanal atresia, mucocele, nasal polyposis, management of epistaxis and epiphora caused by lower lacrimal ducts obstruction, most of the complications are associated to surgical manipulation of the ethmoidal and frontal sinuses. Unless, the olfactory region and depth of OF is known, surgeries will damage the olfactory fossa which has wide variations in its morphology.[19]

Surgical Anatomy and morphometry of olfactory region is of immense value to Neurosurgeons for the management of sellar and parasellar tumors, optic nerve decompression and tumours arising from epithelial olfactory cells normally situated at the upper part of nasal cavity including the cribriform plate of ethmoid which are difficult to access without distortion and without damaging other structures.[20]

Obesity and elevated CSF pressure during growth and development of childhood may ultimately affect the olfactory fossa depth (OFD) in adulthood. Spontaneous cerebrospinal fluid leaks (SCSF) are more common among individuals having higher BMI.[21]

Though olfactory fossa is important surgically, normal morphometry of olfactory region is not described in detail in standard Anatomy books. With regard to less data available on morphology of olfactory fossa in North Karnataka region, this study was undertaken to establish the normal morphology of olfactory fossa. The depth and width of the olfactory fossa, the thickness and angulation of the lateral lamella of the cribriform plate and the length of cribriform plate on both sides in adult males and females and to find out the correlation between depth of the olfactory fossa and BMI by using Multidetector computed tomography (MDCT) in North Karnataka region.

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AIMS & OBJECTIVES

MORPHOLOGY OF OLFACTORY FOSSA AND IT’S CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION

CHAPTER 2.

AIMS AND OBJECTIVES

AIM OF THE STUDY

The aim was to study the relationship between depth of the olfactory fossa and BMI by using MDCT in North Karnataka region.

OBJECTIVES OF THE STUDY

1) To establish the normative morphometry of olfactory fossa and its variation in right and left sides in both genders.

2) To determine the gender differences in the morphology of olfactory fossa on right and left sides.

3) To determine the correlation between olfactory fossa depth and body mass index (BMI).

RESEARCH HYPOTHESIS

1) There is gender difference in the morphometry of olfactory fossa.

2) There is correlation between body mass index and olfactory fossa depth.

REVIEW OF LITERATURE

CHAPTER 3.

REVIEW OF LITERATURE

HISTORY

The word ‘cribriform’ was derived from the latin word ‘cribrum’ which means sieve and ‘forma’ means figure. The term cribriform plate was first described by Hippocrates as soft like a sponge, cartilage, which is not a bone structure, or a flesh one and believed that it would have a role in olfaction. Later, Galen described the cribriform plate as sieve like structure through which the waste products of brain activity were eliminated towards the nose and out of the body.

Leonardo da Vinci also named this sieve as ‘cholatori’ which means to filter. Later Andreas Vesalius and Mateus Realdo Columbus first identified the ethmoid bone and described the distinct character of ethmoid bone.

From the Antiquity until the 16th century, all Anatomists thought that cribriform plate was self standing bone separated from the ethmoid bone. But, later Gabriel Fallopius described the ethmoid bone with high accuracy and argued that the cribriform plate is not a separate bony ossicle but essential part of the ethmoid bone.

Giovanni Filippo Ingrassias was the first one to notice the anterior ethmoid air cells. He also described the terms crista galli, cribriform plate and the perpendicular plate.

Theories around the cribriform plate

Carpensis argued that this sinus that cerebral fluids are eliminated through the sphenoid sinus and not through the cribriform plate. Andreas Vesalius disproved Galen’s theory but accepted the existence of communication between the brain ventricles and the nasal fossa

Thomas Willis eventually disproved Vesalius's theory by pouring milk and ink in to the pituitary fossa of calf. This fluid emerged through jugular veins and not in to the nose. He described the olfactory nerves that cross the cribriform plate in 1664. He named them fascicles nervulets, little strings or filaments: manifold nerve fibers pass through cribriform plate of ethmoid bone. But he wrongly believed that the absorption of the cerebrospinal fluid occurred at this level.

Conrad Victor Schneider argued that the openings in the cribriform plate of the ethmoid bone are for the olfactory nerves and that the cerebral fluids cannot cross from the cranial cavity towards the nose. He demonstrated that only the macerated ethmoid bone displays pores.[1]

DEVELOPMENT OF THE ETHMOID BONE

Development of the Ethmoid is different from other sinuses. Because, the ethmoid sinus develops from the cartilaginous nasal capsule. Other sinuses develop from extensions from the ethmoid via epithelial diverticulums.[2]

The ethmoidal cartilage contains the medial mass and lateral mass in the intrauterine life. The medial mass (the mesethmoid) is present from the sphenoid to the tip of the nasal process. The pair of lateral masses develope from the lateral nasal processes (the ectethmoid) which is present lateral to the olfactory sacs. The end portion of the medial mass persists as the cartilaginous nasal septum. Ossification of the upper portion of medial mass becomes the perpendicular plate and crista galli.[3]

Three ossification centres in the cartilaginous nasal capsule gives rise to the ethmoidal labyrinth and the perpendicular plate of ethmoid bone. One centre appears for the perpendicular plate and one centre appears for each lateral labyrinth. The centre for each lateral labyrinth is seen during sixteenth and twentieth week of intrauterine life.[4]

Development of Ethmoid Air Cells

At about three months of intrauterine life, ethmoid air cells will start developing.[1] Ethmoid sinus is not formed from single cell. Instead bony septa divide in to air cell and forms many air cells.[5] At birth, there will be three to four cells. But, radiologically it's difficult to observe at birth till one year of age. They reach the adult size by twelve years of age.[4]In adults, there will be ten to fifteen ethmoidal air cells.[6]

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Development of Crista Galli

Although some ossification has been noticed in the fetus by the end of third month,[3] most ossification of the Crista galli begins at about one-two months of age. Then, there will be rapid ossification of the Crista galli till fourteen months of age. Then ossification slows down up to twenty four months of age. Sometimes a separate ossification centre occurs at the tip of the crista galli at about three months of age. [7]The ossification of cribriform plate takes place partly from perpendicular plate of ethmoid and partly from the lateral labyrinths. Complete ossification is seen at second year of age.[4]

Development of Cribriform Plate

Cribriform plate is not seen during fetal life. It may appear as indentation between the olfactory nerves.[8] Ossification of the cribriform plate starts in attachment of the superior and inferior turbinates then it extends till it reaches the crista galli at 2nd month of age. Ossification of the cribriform plate starts in its anterior region and then it extends posteriorly during first post-natal month.[9]

Development of Perpendicular Plate

At one year, the perpendicular plate of the ethmoid bone ossifies from the median centre. Later it merges with the lateral labyrinths in the second year.[4]

Development of ethmoidal labyrinths

The centre for each labyrinth appears in fourth and fifth month of foetal life. They later extend in to the ethmoidal conchae.[4] During 8th week of foetal life, the cartilaginous nasal capsule resembles the shape of ‘M’. Then the lateral wall of capsule shows curved foldings leading to the formation of ethmoturbinals at ninth to ten week of intrauterine life.[10] Intially, there will be five to six ethmoturbinals. Only three to four persists. These ethmoturbinals entangle to form ethmoidal labyrinths. [11] Labyrinths are partially ossified at birth.[4]

First ethmoturbinal develops to form agger nasi and the lateral extension of the uncinate process. Second ethmoturbinal develops to form middle turbinate. Third ethmoturbinal develops to form superior turbinate. Fourth and fifth ethmoturbinals develop to form supreme turbinate. Complete growth of the ethmoid bone occurs by seven years of life.[10]

Ossification of ethmoid bone

The ethmoidal bone is ossified from three centres in cartilaginous nasal capsule. One centre appears for each labyrinth and one centre appears for the perpendicular plate. The centres for the labyrinths appear during the fourth and fifth foetal months. Then, it extends into the ethmoid conchae. At birth, the labyrinthsare ill-developed and partially ossified. Remaining parts are cartilaginous. Ossification of perpendicular plate appears during the first year. The fusion of the three components to form single bone takes place in around second and third years of age.

The ethmoidal air cells develop as narrow pouches at about 3 months of intra-uterine life. They are present at birth. They grow slowly and reach the adult size by the age of 12 years.[12]

Development of olfactory nerve.

During fourth week of development, five swellings called facial prominences appear in face from the first and second pharyngeal arches. These are the frontonasal prominence and the paired mandibular and maxillary prominences. On each side of the frontonasal prominence, an area of thickened ectoderm called the olfactory placodes forms around the fourth week of intrauterine life.[1]

The olfactory organ arises from both olfactory placode and cranial Neural Crest cells (NC). The olfactory placode contributes to the formation of the olfactory sensory neurons and supporting cells of the olfactory epithelium (OE). The NC contributes to the structural components of the nose.[13,14 & 15]

The olfactory placodes grows in size till sixth week when the each placode invaginates to form the nasal pits. The olfactory placode is one of the unique placodes. It has the capacity to give rise to glial cells and stem cells which inturn gives rise to various cell types of the OE continuously throughout life.[1] Olfactory ensheathing cells along the nonmyelinated olfactory nerves are derived from the olfactory placode. [15, 16, 17 & 18]

Majority of cells in the Olfactory Epithelium are derived from the olfactory placode but, Neural Crest-derived cells can form all cell types of the Olfactory Epithelium.[19]

REVIEW OF LITERATURE ON OLFACTORY FOSSA

DEPTH OF OLFACTORY FOSSA

The incidence of Keros type I was 23.44%, type II keros was 70.83% and type III was 5.73%. Keros type III was less common on right side and more common on the left side in a study done in New Delhi, India among 32 dry skulls by using a hydroxyphilic siloxane based gel.[20]

Vinay kumar revealed 87% of cases of Keros type OF, 11% cases of keros type II OF & 2% of cases of Keros type III OF among 60 coronal CT scans in Trichy, Tamilnadu, India. CT Scan of Mean height of ethmoidal skull base varies between 3.7 mm to 15.4 mm with mean height of 10.05 mm at the level of anterior ethmoid artery canal. Low ethmoidal skull base was found in 2% of females.[21]

A study done by Satish Nair on 180 patients in Bangalore, Karnataka revealed 17.2% of cases of Keros type I OF, 77.2% cases of keros type II OF and 5.6% of cases of Keros type III OF on 180 direct coronal CT scans.[22]

Basak et al studied CT scans of 64 children and found most common Keros type II OF (53%) when compared to other types of OF. Keros type III was 38% and Keros type I was 9% .[23]

Jang et al studied 205 predominantly adult patients CT scan and noticed that Keros type II was most common (69.5%), followed by type I Keros (53.8%). Type III Keros was not found in this study.[24]

Anderhuber et al studied CT scans of children aged between zero and fourteen years. Type II was most common (70.6%). Type I Keros was 14.2% and Type II was 15.2%.[25]

Souza et al studied specifically 200 CT scans of adult patients and observed that the Keros type II olfactory fossa was most common (73.3%), followed by Keros type I OF

(26.2%) and Keros type III OF (0.5%).[26]

WIDTH OF OLFACTORY FOSSA

The width of OF increases before backwards steadily.The mean width of OF was 3.8 mm and 3.6 mm on right and left sides respectively below the crista galli. The width of OF was 5.2 mm and 5.1 mm on right and left sides respectively in the posterior one third of OF. [27]

The mean width of OF was 0.44mm and 0.39mm on right and left sides respectively in a study done in New Delhi, India among 32 dry skulls using a hydroxyphilic siloxane based gel.[20]

The average width of OF was 4.57mm and 4.49mm on on right and left sides respectively in a study done in USA on 31 human skull specimens by Daniel HC.[28]

The average width of OF was 0.96mm and 0.89mm on right and left sides respectively in a study done by Savvateeva DM on 111 patients by using digital volume tomography.[29]

ANGLE OF OLFACTORY FOSSA

The mean angle of OF was $130.58^{0}$and 128.74^{0}on right and left sides respectively in a study done by Tony GJ.[20]

The mean angle of OF was $159.42^{0}$and 153.26^{0}on right and left sides respectively in a study done by Elwany.[30]

Luigi maione et al observed angle of LLCP in 37 kallmann syndrome patients and compared with the non congenital hypogonadotropic hypogonadism patients in France. Significant wider angles of LLCP was observed in Kallmann syndrome.[31]

THICKNESS OF LLCP

A study done by Keast revealed the thickness of LLCP was from 0.2 to 0.05 mm on 226 patients in European population.[32]

LENGTH OF CRIBRIFORM PLATE

A study conducted by Daniel CH revealed the mean length of the cribriform plate was 21.28mm (range 15.25- 27.73 mm, SD 3.30) in 31 Human skull specimens.[28]

A study conducted by Elwany revealed the mean length of the cribriform plate was 6.85mm in by using 300 high resolution Multislice computed tomography scans.[30]

A study conducted by Savvateeva DM revealed the mean length of the cribriform plate was 21.1mm in 111 scans by using Digital volume tomography.[29]

CLINICAL ANATOMY OF ETHMOID BONE

Normal radiography does not reveal the fractures of ethmoid as it inclined at an angle of 45˚. Hence CT scans has an important role in detecting the skull base fractures especially the ethmoid bone.[4]

Fractures of ethmoid bone

Common sites of anterior skull base fractures associated with CSF leaks include the cribriform plate, the roof of the sphenoid sinus, and posterior wall of frontal sinus. Because the dura is adherent to the bone in these regions of skull base.[33]

Congenital defect in the cribriform plate (CP) leads to spontaneous CSF leak which allows the extension of dura and arachnoid along the olfactory nerve fibers through the cribriform plate.[34]

Le fort III fracture extends through the nasal base and continues across the ethmoid bone in the posterior side. This fracture separates the entire mid-facial skeleton from the cranial base.

CSF Rhinorrhoea may result from dural tear which is associated with the fracture of the cribriform plate of the ethmoid bone or from skull fracture. It extends through the posterior wall of the frontal sinus. Females are at risk to develop CSF leakage because their bones are thinner. [4]

Dehiscence of the lamina papyracea is characterized by protrusion of orbital fat through a gap in the anterior ethmoid cell can be mistaken as infectious or tumoral process during endoscopic surgery.[35]

Injuries of ethmoid bone during surgeries

Most of the traumatic CSF rhinorrhoea cases are the result of surgeries involving the skull base. Injuries to Lateral lamella of CP and the posterior ethmoid roof can occur during endoscopic sinus surgeries. Injury to the lateral lamella of the cribriform plate can occur while reaching the anterior ethmoid or frontal recess or the middle turbinate close to the skull base. It can occur more frequently on the patient's right side because most surgeons are right handed individuals. There is a tendency for the angle of surgical approach to drift medially toward the lateral lamella. These injuries can be minimised if patient's head is turned towards the surgeon and if aligned with angle of the approach.[36]

The word “spontaneous” CSF rhinorrhea describes the nasal discharge of Cerebrospinal fluid not related to trauma, malformation, surgery, tumor or previous radiation therapy. It can be due to small osteodural interruption along the cribriform plate. It can lead to the olfactory cleft, defects in the lateral lamella, defect at the junction of the cribriform plate with the lateral lamella and fovea ethmoidalis (FE) and defects along the the anterior ethmoid artery.[37]

Spontaneous CSF fistulas are more common at the cribriform plate of ethmoid bone, tegmen tympani, perisella and sphenoid sinus.[38]

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MATERIAL &METHODS

CHAPTER 4.

MATERIALS AND METHODS

RESEARCH METHODOLOGY

Type of study: Hospital based descriptive study

1) Sample size estimation for morphology of olfactory fossa.[1]

Sample size calculation was done by using Open Epi Software version 2.3.1

At 95 % confidence level

32 % of Keros II has height asymmetry = p

At 10% relative precision

Sample size calculated was **816 ≈ 820**

2) Sample size required for studying the correlation between BMI and olfactory fossa depth

Sample size calculation was done by using Medcalc Statistical Software

At 95% confidence level

80% power of study

Correlation coefficient of BMI and olfactory fossa depth: 0.31[1]

$Z\alpha = 1.96$ $\qquad C = 0.5 \times \ln\left\{\frac{1+r}{1+r}\right\}$

$Z\beta = 0.84$ $\qquad = 0.321$

$$\text{Total size } N = \left\{\frac{Z\alpha + Z\beta}{c}\right\}^2 + 3$$

Calculated sample size: **79 ± 80**

Statistical analysis : Pearson's correlation co-efficient was calculated.

p value less than 0.05 was observed as statistically significant in all parameters.

METHODS

SOURCE OF DATA

Source of data – Paranasal multidetector computed tomographic scans of **820** patients were collected in North Karnataka region, Karnataka, India. Scans were collected after Institutional Ethics Committee clearance. Population stratification of 820 patients was done in 13 districts of North Karnataka region, Karnataka, India.

61 scans were collected from Raichur, 54 scans from Bidar, 34 scans from Gadag, 77 scans from Bellary, 37 scans from Yadagiri, 60 scans from Bagalkot, 68 scans from Bijapur, 59 scans from Dharwad, 150 scans from Belgaum, 51 scans from Haveri, 44 scans from Koppal, 45 scans from Uttar Kannada and 80 scans from Kalburgi were collected from North Karnataka region.

Paranasal sinuses MDCT scans of 80 obese patients were collected from Bagalkot district of north Karnataka region. All the scans were analysed for morphometry by using RadiAnt DICOM viewer.

Inclusion criteria

- As the ethmoid bone completely ossifies around 16 years of age, normal PNS Computed Tomographic scans of male and female patients above the age of 16 yearswere included in 820 patients in the study.
- PNS CT scans of patients above the age of 16 years with BMI greater than 25 were included in 80 patients in the study.

Exclusion criteria

- CT images of male and female patients less than the age of 16 years and Computed Tomographic images of patients with facial anomalies, nasal or paranasal trauma, tumours or conditions involved in bone destruction and surgeries were excluded from the study in 820 patients.
- BMI less than 25 were excluded in this study in 80 patients.

METHODS

MDCT scan of paranasal air sinuses (PNS) were collected from November 2018 to May 2021. The patients were informed and instructed during MDCT of PNS about the procedure after the informed written consent. Axial Computed Tomographic scan images of 3mm thickness were obtained by using bone window. After exposure, the images were reconstructed to 0.75mm thickness. The upper boundary of infraorbital foramen was taken as landmark in the coronal scans. This point shows the maximum depth of OF. The length of the lateral lamella of cribriform plate (CP) determines the depth of the olfactory fossa.The length of the LLCP was obtained when the height of CP was subtracted from the height of medial ethmoidal roof point (MERP) on right and left sides in male and female patients.

The depth of the olfactory fossa was measured in direct coronal scans at the level of infraorbital foramen as shown in figure 13.

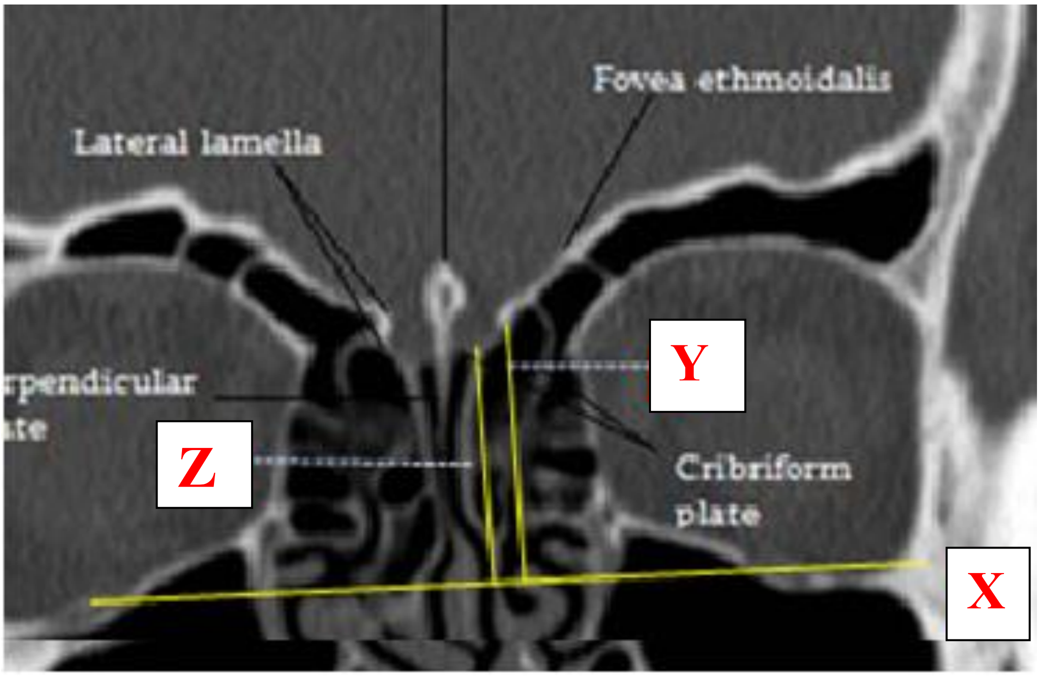

Figure13: showing X line, Y line and Z line in coronal MDCT scan.

Line X was drawn as transverse line in the coronal scans. This X line was extending between both upper boundry of infraorbital foramen. Then, line Y was drawn as vertical line which extends from X line to the metting point of Fovea ethmoidalis with LLCP. Line Z was drawn as a straight line which extends from the meeting point of the cribriform plate with the LLCP to X line. Line Y represents the medial ethmoid roof point (MERP) while line Z represents the height of the CP. The depth of the OF (H) was considered as height of the roof of the ethmoid bone or height of LLCP. The depth of olfactory fossa‘‘H’’ was calculated as the result of subtraction of length of line Z from the length of line Y in millimeters (H =Y− Z).[2] Olfactory fossa depth was classified according to Keros classification.[3]

The width of the olfactory fossa was measured from outer margin of the crista galli to MERP on both the sides in both the genders in direct coronal CT scan of patients The width of OF was calculated at the level of upper boundary of infraorbital foramen in coronal scans as shown in figure 14.

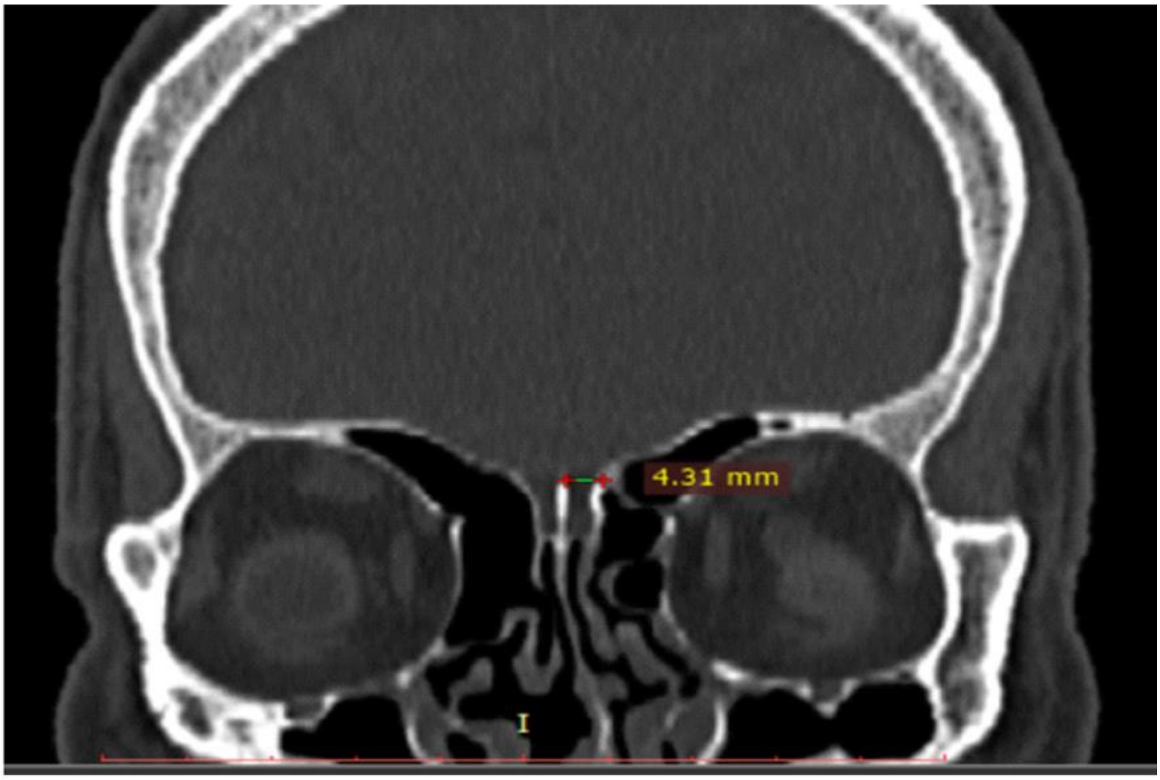

Figure 14: Measurement of width of left olfactory fossa in coronal section of MDCT scan of the patient.

The thickness of the LLCP was calculated from the outer margin of the bone to the inner margin of the bone at the middle of LLCP on both the sides in both the genders in direct coronal CT scan of patients. The thickness of LLCP was calculated at the level of infraorbital foramen in direct coronal scans as shown in figure 15.

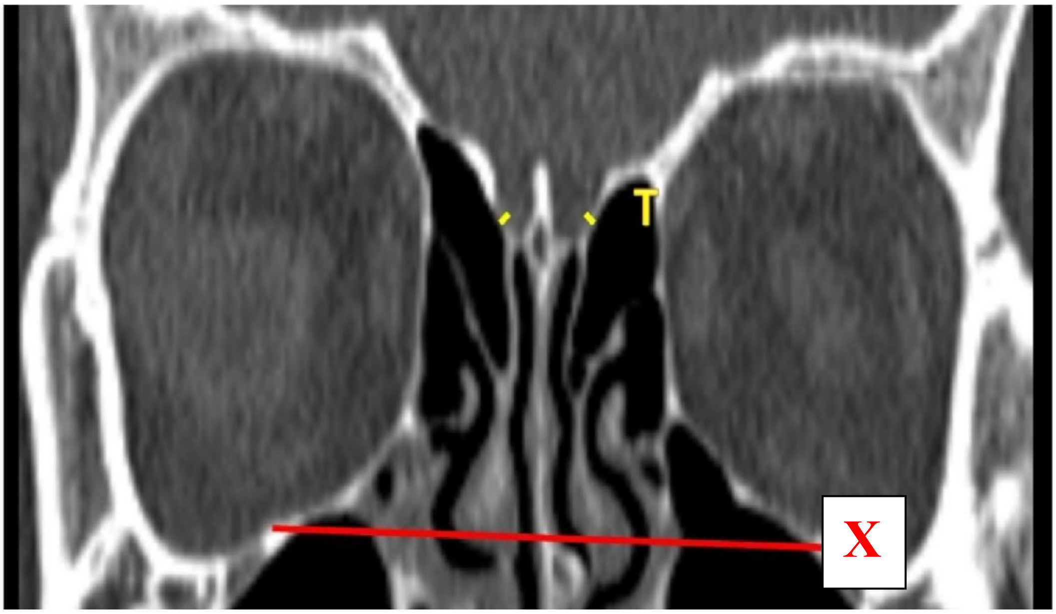

Figure 15: coronal scan showing the thickness of LLCP at the centre of the infraorbital foramen

A=line at the level of infraorbital foramen
T=thickness of LLCP

The angle of the LLCP was measured between the line drawn along LLCP and a horizontal line drawn at the cribriform plate of the ethmoid bone. The angle was calculated on both the sides in both the genders in direct coronal CT scan of patients. The angle of OF was measured at the level of infraorbital foramen in direct coronal scans as shown in figure 16.

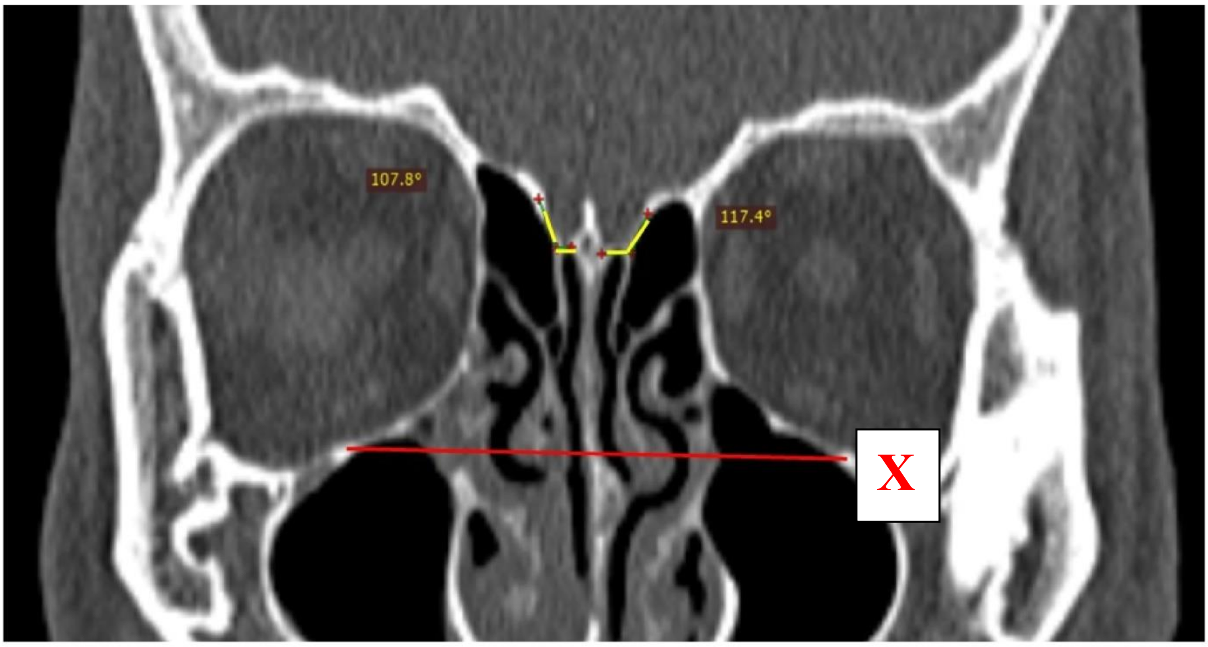

Figure 16: Coronal scan showing the angle of LLCP with cribriform plate at the centre of infraorbital foramen.

The length of CP was calculated at two points in sagittal plane: Anterior and Posterior. The anterior end was taken at the junction between the posterior wall of the frontal sinus and the cribriform plate. The posterior point was taken at the junction between the posterior edge of cribriform plate and the anterior edge of planum sphenoidale.[4] The length of CP was measured in both the genders in CT scans of patients. The length of CP was measured at the level of infraorbital foramen in direct coronal scans as shown in figure 17.

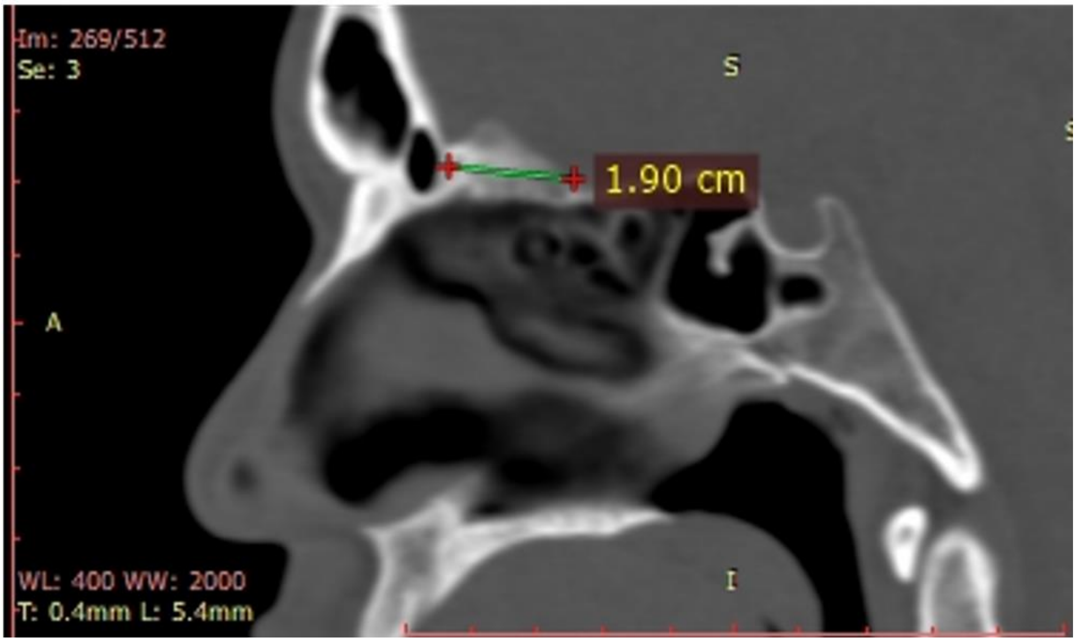

Figure 17: Sagittal scan showing the length of cribriform plate at the centre of infraorbital foramen

BMI was calculated by using the following formula,

BMI= Weight (in kg)÷ height ^{2}(in metres).

Classification of underweight, overweight and obesity according to their BMI was done according to WHO guidelines.[5]

The depth of the olfactory fossa was correlated with BMI of individuals to find out any association existing between them.

STATISTICS

Side symmetry and relation of morphology of olfactory fossa in both genders were calculated by using Student 't' (unpaired) test.

Correlation between the depth of olfactory fossa and BMI was calculated by using Pearson's correlation. The data was considered statistically significant if p is less than 0.05.

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RESULTS

MORPHOLOGY OF OLFACTORY FOSSA AND
IT'S CORRELATION WITH BODY MASS INDEX
IN NORTH KARNATAKA REGION

CHAPTER 5.

RESULTS

Comparison of the mean±SD of Medial ethmoidal roof point (MERP), CP, depth of OF, and width of OF, and their significance in the present study on both sides in both genders is shown in table 3, 4 and 5.

Table 3: Comparison of morphology of olfactory fossa between right and left sides in male patients.

Males n =474	Right side Mean±SD (in mm)	Left side Mean±SD (in mm)	P value
MERP ht	26.70±3.17	26.74±3.26	0.9465
CP ht	21.76±2.98	22.08±2.94	0.09639
OF depth	4.94±1.99	4.66±1.86	0.003982
OF width	5.24±2.77	4.84±2.27	0.01521
Thickness of LLCP	1.25±0.65	1.20±0.52	0.1913
Angulation of OF	106.08±21.19	109.35±16.64	0.008368
CP length	21.40±8.84		

MERP= medial ethmoidal roof point, ht=height, OF=olfactory Fossa, CP=Cribriform plate, LLCP= lateral lamella of cribriform plate.

Comparison of morphology of olfactory fossa was done between right and left sides in 474 male patients. In male patients, the mean OF depth was 4.94±1.99mm on right side and 4.66±1.86mm on left side. The mean OF width was 5.24±2.77mm on right side and 4.84±2.27mm on left side. The mean thickness of LLCP was 1.25±0.65mm on right side and 1.20±0.52mm on left side. The mean angulation of OF was 106.08±21.19^{0}on right side and 109.35±16.64^{0}on left side. The mean CP length in male patients was 21.40±8.84 mm. Statistically significant differences were observed in the mean of OF depth, width of OF and angle of LLCP when compared between two the sides in male patients. Statistically significant differences were not found in mean of MERP height, CP heightand thickness of LLCP among male patients as shown in Table 3.

Table 4: Comparison of morphology of olfactory fossa between right and left sides in female patients.

Females n=346	Right side Mean±SD (in mm)	Left side Mean±SD (in mm)	Pvalue
MERP ht	25.32±3.15	25.32±3.02	0.999
CP ht	20.76±2.91	21.02±2.69	0.2227
OF depth	4.55±1.96	4.29±1.88	0.07539
OF width	4.93±1.31	4.68±1.38	0.01478
Thickness of LLCP	1.21±0.59	1.24±0.54	0.4856
Angulation of OF	110.53±18.82	110.21±19.23	0.8250
CP Length	19.97±5.55		

MERP= medial ethmoidal roof point, ht=height, OF=olfactory Fossa, CP=Cribriform plate, LLCP= lateral lamella of cribriform plate.

Comparison of morphology of olfactory fossa was done between right and left sides in 346 female patients. In female patients, the mean OF depth was 4.55±1.96mm on right side and 4.29±1.88mm on left side. The mean OF width was 4.93±1.31mm on right side and 4.68±1.38mm on left side. The mean thickness of LLCP was 1.21±0.59mm on right side and 1.24±0.54mm on left side. The mean angulation of OF was 110.53±18.82^{0}on right side and 110.21±19.23^{0}on left side. The mean CP length in female patients was 19.97±5.55mm. Statistically significant difference was observed in the mean of width of OF when compared between two sides in female patients. Statistically significant differences were not found in mean of MERP height, CP height, OF depth, angle of LLCP and thickness of LLCP as shown in Table 4.

Table 5: Comparison of morphology of olfactory fossa on both the sides in male and female patients.

n=820		Males (n=474) Mean±SD (in mm)	Females (n=346) Mean±SD (in mm)	Pvalue
MERP ht	R	26.70±3.17	25.32±3.15	0.0000001
	L	26.74±3.26	25.32±3.02	0.0000001
CPht	R	21.76±2.98	20.76±2.91	0.000001952
	L	22.08±2.94	21.02±2.69	0.000000163
OFdepth	R	4.94±1,99	4.55±1.96	0.005406
	L	4.66±1.86	4.29±1.88	0.005222
OF width	R	5.24±2.77	4.93±1.31	0.05397
	L	4.84±2.27	4.68±1.38	0.2450
Thickness of LLCP	R	1.25±0.65	1.21±0.59	0.3660
	L	1.24±0.54	1.24±0.54	0.9999999
Angulation of OF	R	106.08±21.19	110.53±18.82	0.001924
	L	109.35±16.64	110.21±19.23	0.4941
CP Length		21.40±8.84	19.97±5.55	0.008171

MERP= medial ethmoidal roof point, ht=height, OF=olfactory fossa, CP=Cribriform plate, LLCP= lateral lamella of cribriform plate, R= right side, L= left side

Comparison of morphology of olfactory fossa was done on both the sides between 474 male and 346 female patients. Statistically significant differences were observed in the mean of MERP height, CP height, OF depth when compared between two sides in male and female patients. Statistical significant differences were not found in mean of OF width and thickness of LLCP. The mean angulation of OF was significant on right side when compared between males and females. Whereas on left side, the mean angulation of OF was not significant when compared between males and females. The mean CP length was significant when compared between males and female patients as shown in Table 5.

Table 6: Comparison of morphology of olfactory fossa between male and female patients.

n =820	Males Mean±SD (in mm)	Females Mean±SD (in mm)	P value
MERP ht	26.72±3.21	25.32±3.08	0.0000001
CP ht	21.92±2.96	20.89±2.80	0.0000001
OFdepth	4.80±1.92	4.42±1.92	0.00007879
OF width	5.04±2.52	4.80±1.34	0.01751
Thickness of LLCP	1.22±0.58	1.22±0.56	0.9999999
Angulation of OF	107.71±18.91	110.37±19.025	0.005096
CP Length	21.40±8.84	19.97±5.55	0.0001109

CP=Cribriform plate MERP= medial ethmoidal roof point, LLCP= lateral lamella of cribriform plate.

Comparison of morphology of olfactory fossa was done between 474 male and 346 female patients. The mean OF depth was 4.80±1.92mm in male patients and 4.42±1.92mm in female patients. The mean OF width was 5.04±2.52mm in male patients and 4.80±1.34mm in female patients. The mean thickness of LLCP was 1.22±0.58mm in male patients and 1.22±0.56mm in female patients. The mean angulation of OF was 107.71 ± 18.91^{0}in male patients and 110.37 ± 19.025^{0} in female patients. The mean CP length was 21.40±8.84mm in male patients and 19.97±5.55 in female patients. Statistically significant differences were observed in the mean of MERP height, CP height, OF depth, angulation of OF and CP length when compared between male and female patients. Statistical significant differences were not found in mean of OF width and thickness of LLCP when compared between males and females as shown in Table 6.

Comparison of morphology of olfactory fossa between male and female patients is shown in chart 1.

Chart 1. Comparison of morphology of olfactory fossa between male and female patients.

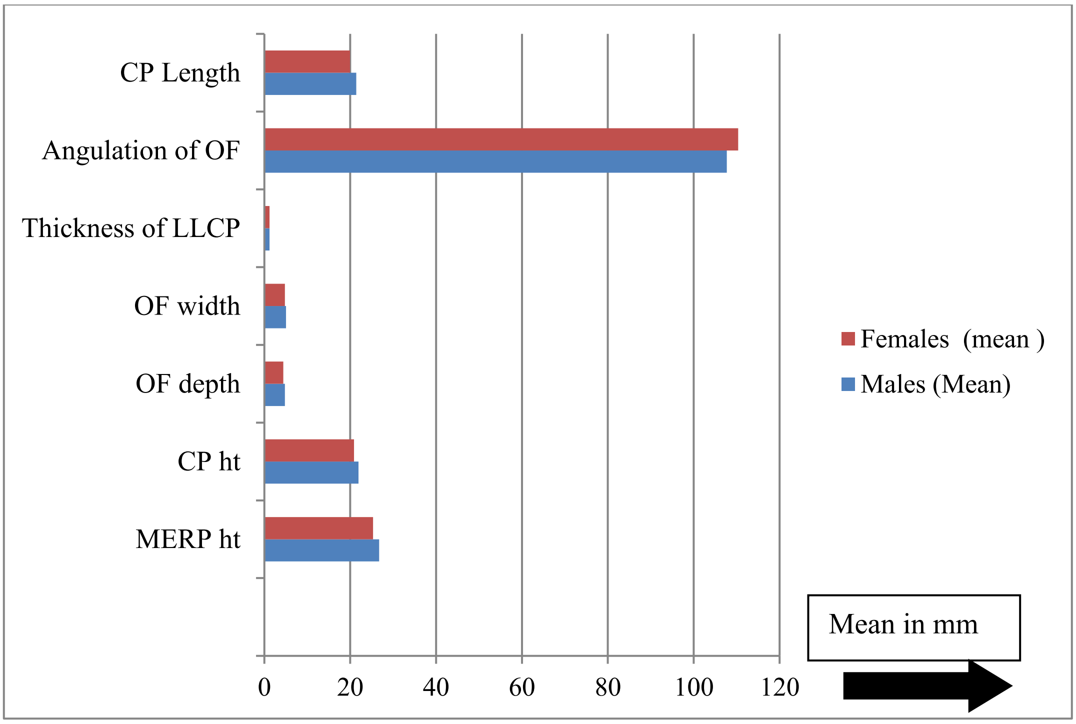


Table 7: Comparison of morphology of olfactory fossa between right and left sides in patients.

n =820	Right side Mean±SD (in mm)	Left side Mean±SD (in mm)	P value
MERP ht	26.01±3.16	26.03±3.14	0.89
CP ht	21.26±2.94	21.55±2.81	0.04
OFdepth	4.74±1.97	4.47±1.87	0.004
OF width	5.08±2.04	4.76±1.82	0.00082
Thickness of LLCP	1.23±0.62	1.24±0.54	0.72
Angulation of OF	108.3±20	109.78±17.93	0.11
CP Length	20.68 ±7.19		

CP=Cribriform plate MERP= medial ethmoidal roof point, LLCP= lateral lamella of cribriform plate.

Comparison of morphology of olfactory fossa was done between right and left sides in 820 patients. The mean OF depth was 4.74±1.97mm on right side and 4.47±1.87mm on left side. The mean OF width was 5.08±2.04mm on right side and 4.76±1.82mm on left side. The mean thickness of LLCP was 1.23±0.62mm on right side and 1.24±0.54mm on left side. The mean angulation of OF was 108.3±20^{0}on right side and 109.78±17.93^{0}on left side. The mean CP length was 20.68 ±7.19mm. Statistically significant differences were observed in the mean of CP height, OF depth and OF width when compared between right and left sides. Statistically significant differences were not found in mean of MERP height, thickness of LLCP and angulation of OF when compared between right and left sides as shown in Table 7.

Comparison of morphology of olfactory fossa between right and left sides in patients is shown in chart 2.

Chart 2: Comparison of morphology of olfactory fossa between right and left sides in patients.

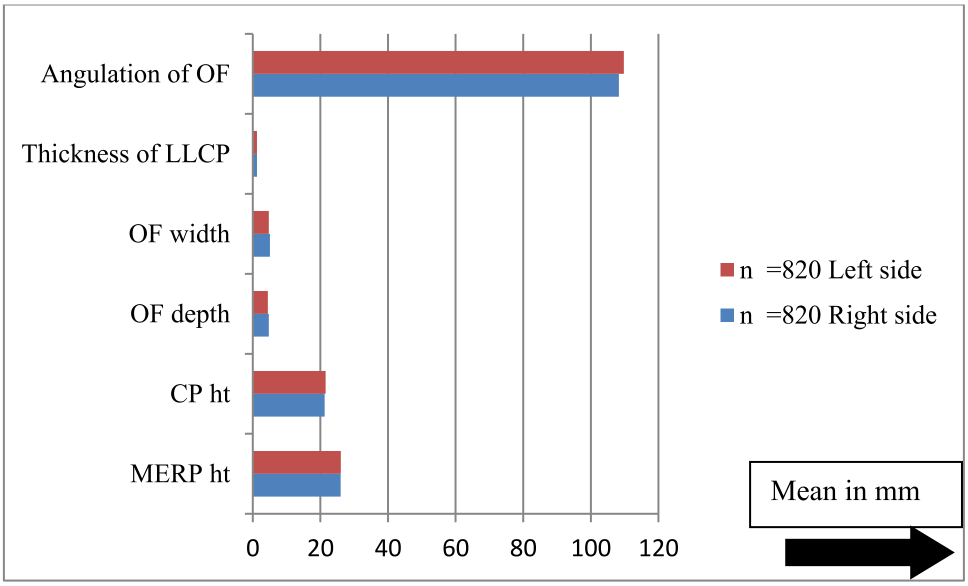


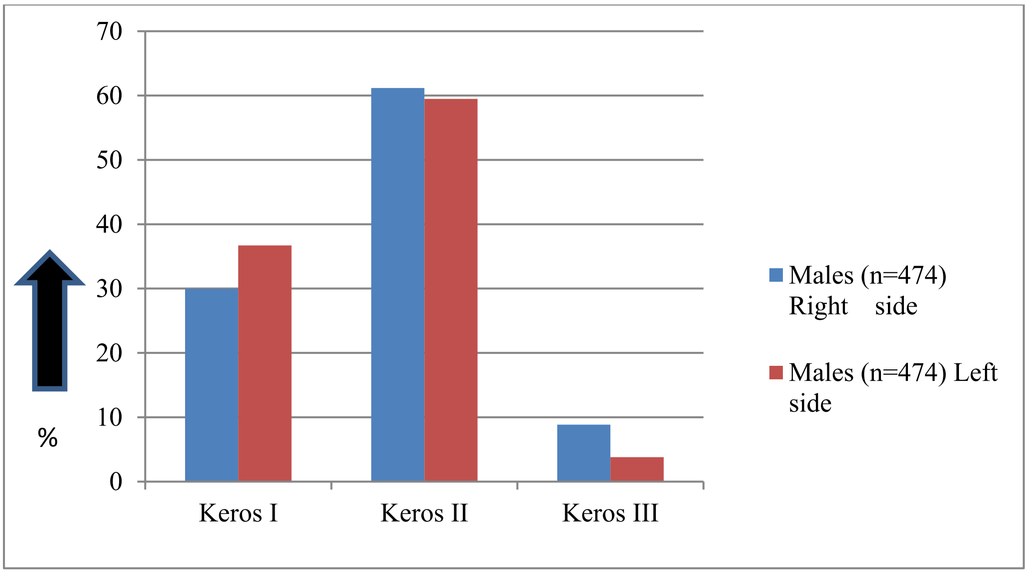
TABLE 8: Comparison of keros types of olfactory fossa on both the sides in male and female patients in present study.

Keros	Males n=474				Females n=346			
Types	Right side		Left side		Right side		Left side	
	Cases	%	Cases	%	Cases	%	Cases	%
Keros I	142	29.95	174	36.70	117	33.81	164	**47.39**
Keros II	290	**61.18**	282	**59.49**	213	**61.56**	159	45.95
Keros III	42	8.86	18	3.79	16	4.62	23	6.64

Comparison of keros types of olfactory fossa was done on both the sides in 474 male and 346 female patients in the present study. Among male patients, type I keros of OF was found in 29.95% of cases on right side and 36.7% on left side. Type II keros of OF was found in 61.18% of cases on right side and 59.49% on left side. Type III keros of OF was found in 8.86% of cases on right side and 3.79% on left side. Among female patients, type I keros of OF was found in 33.81% of cases on right side and 47.39% on left side. Type II keros of OF was found 61.56% of cases on right side and 45.95% on left side. Type III keros of OF was found in 4.62% of cases on right side and 6.64% on left side. Type II keros of OF depth was common in both sides of male patients. In females, type II keros of OF depth was common on right side and type I keros of OF depth was common on left side as shown in table 8.

Comparison of keros types of olfactory fossa on both the sides in male patients in present study is shown in chart 3.

Chart 3: Comparison of percentage of keros types of olfactory fossa on both the sides in male patients in present study.



Comparison of keros types of olfactory fossa on both the sides in female patients in present study is shown in chart 4.

Chart 4: Comparison of percentage of keros types of olfactory fossa on both the sides in female patients in present study.

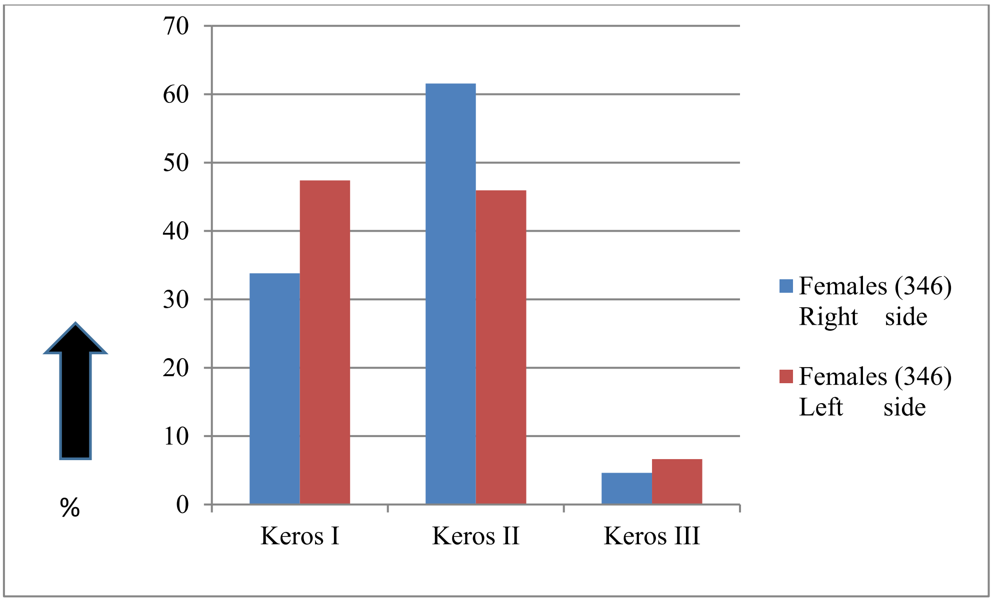


Table 9: Comparison of symmetry of olfactory fossa in male and female patients in present study.

	Male (n=474)		Female (n=346)	
	Cases	%	Cases	%
Symmetry	333	**70.25**	217	**61.71**
Asymmetry	141	29.74	129	37.28

Comparison of symmetry of olfactory fossa was done in male and female patients in present study. Symmetry of OF was seen in 70.25 % of cases in 474 male patients and 61.71 % of cases in 346 female patients as shown in table 9.

Comparison of symmetry of olfactory fossa in male and female patients in present study is shown in chart 5.

Chart 5: Comparison of percentage of symmetry of olfactory fossa in male and female patients in present study.

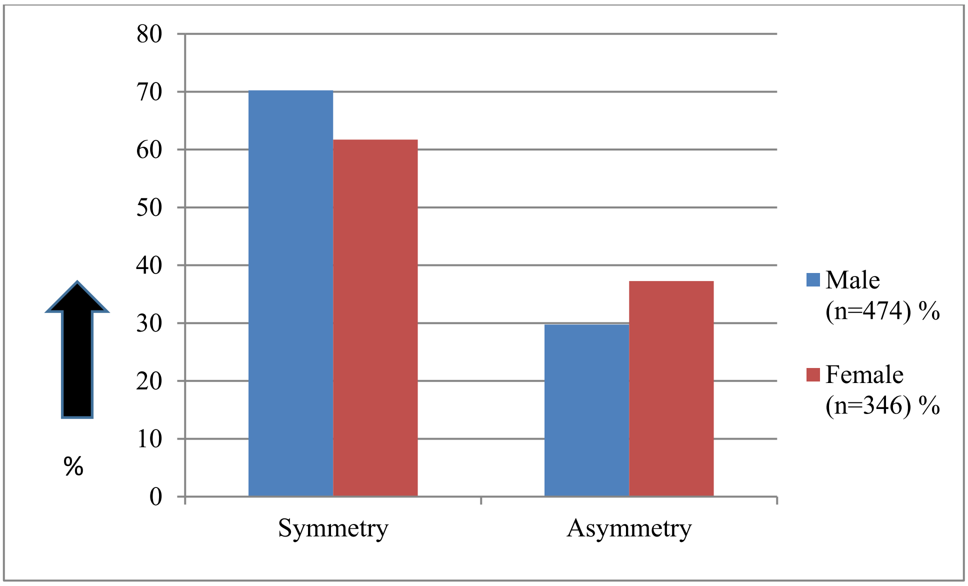


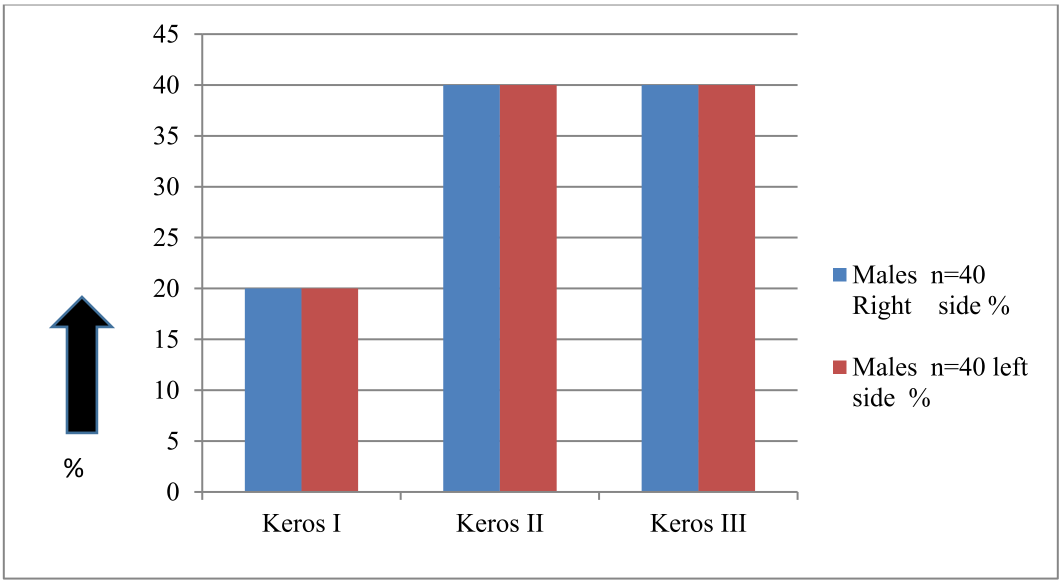
Table 10: Comparison of keros types of olfactory fossa on both the sides in male and female patients in present study. (80 BMI cases)

Keros	Males n=40				Females n=40			
Types	Right side		Left side		Right side		Left side	
	Cases	%	Cases	%	Cases	%	Cases	%
Keros I	8	20	8	20	4	10	8	20
Keros II	16	**40**	16	**40**	28	**70**	12	30
Keros III	16	**40**	16	**40**	8	20	20	**50**

Comparison of keros types of olfactory fossa on both the sides in 40 male and 40 female patients (BMI cases) in the present study. Among male patients, type I keros of OF was found in 20% of cases on right side and 20% on left side. Type II keros of OF was found in 40% of cases on right side and 40% on left side. Type III keros of OF was found in 40% of cases on right side and 40% on left side. Among female patients, type I keros of OF was found in 10% of cases on right side and 20% on left side. Type II keros of OF was found 70% of cases on right side and 30% on left side. Type III keros of OF was found in 20% of cases on right side and 50% on left side. Keros type II and type III of OF was most common on both the sides in 40 male patients. Keros type II of OF was most common on right side and type III keros of OF was most common on left side in 40 female patients as shown in table 10.

Comparison of percentage of keros types of olfactory fossa on both the sides in male patients in present study is shown in chart 6.

Chart 6: Comparison of percentage of keros types of olfactory fossa on both the sides in male patients in present study.



Comparison of percentage of keros types of olfactory fossa on both the sides in female patients in present study is shown in chart 7.

Chart 7: Comparison of percentage of keros types of olfactory fossa on both the sides in female patients in present study.

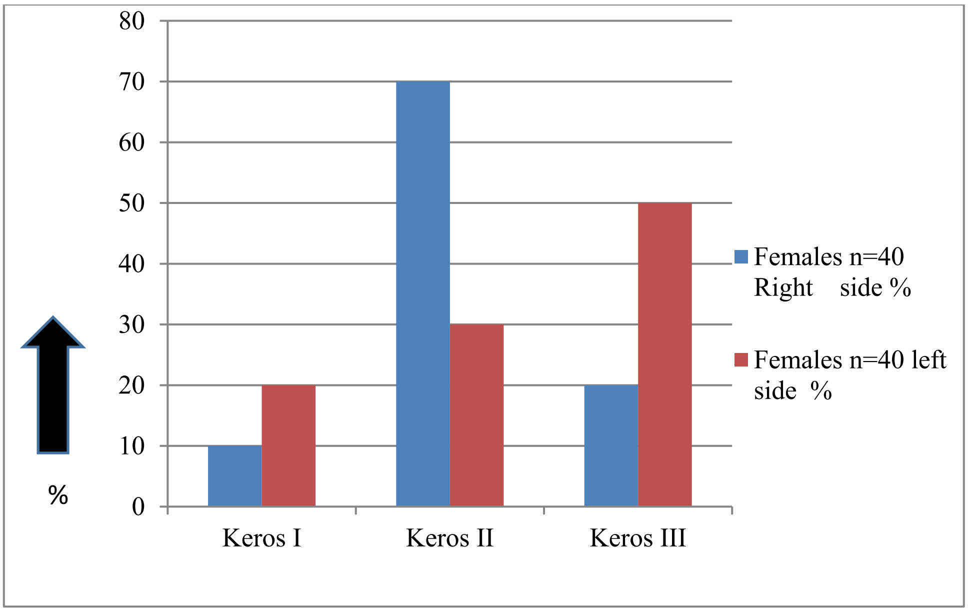
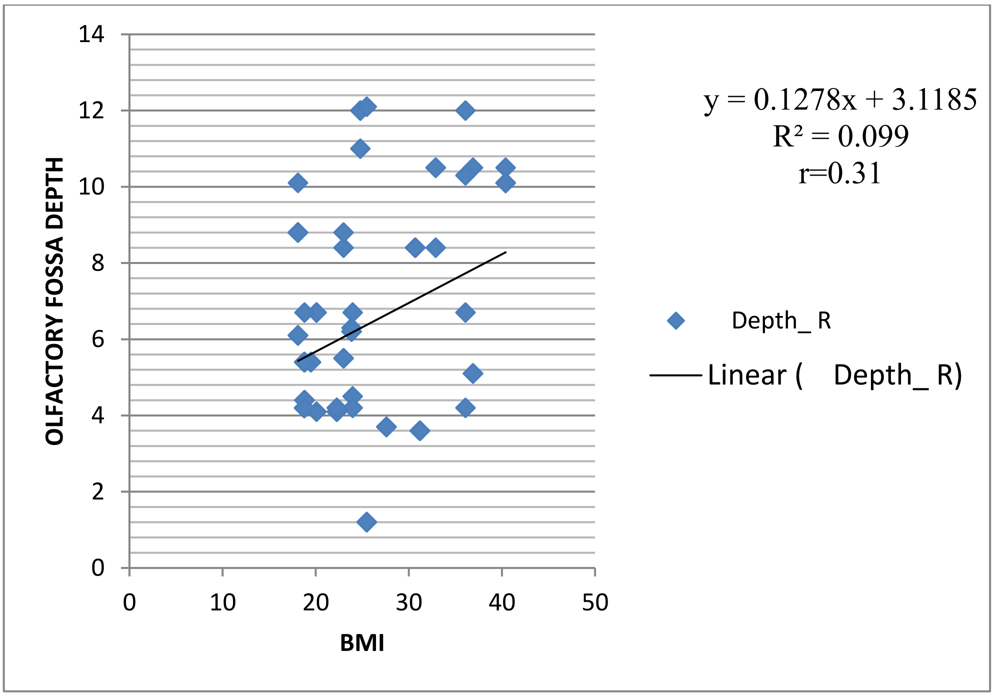


Table 11: Correlation between the BMI and depth of olfactory fossa by pearson's correlation in male and female patients in 80 BMI cases (present study).

80 BMI CASES		RIGHT OLFACTORY FOSSA	LEFT OLFACTORY FOSSA
BMI	Pearson Correlation ®	0.246	0.229
	P value	0.028	0.04
	sig	Significance ($p<0.05$)	Significance ($p<0.05$)
	N	80	80

Correlation between the BMI and depth of olfactory fossa was done by pearson's correlation among 80 BMI cases in the present study. When we compare the BMI cases with depth of OF, R value was 0.315 on right side of OF and 0.239 on left side of OF. Statistically significant positive correlation was found between both the sides of OF depth and BMI as shown in table 11.

CHART 8: Correlation between BMI and OF depth.



There was positive correlation between BMI and OF depth. So, BMI is directly proportional to the depth of OF as shown in chart 8.

DISCUSSION

MORPHOLOGY OF OLFACTORY FOSSA AND IT'S CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION

CHAPTER 6.

DISCUSSION

Various factors likethin LLCP, asymmetry of ethmoidal fovea, types of OF depth and course of anterior ethmoidal artery are at risk areas in anterior skull base surgeries and FESS as they lead to iatrogenic injuries. These injuries lead to complications like meningitis, intracranial hypotension from CSF leak, meningocele and menigoencephalocele. Therefore pre-operative assessment of OF is necessary to decrease these complications.

In our present study there were 474 male patients and 346 female patients. The morphometry of OF was observed and measured in MDCT scans of patients. Then the depth of OF was correlated with BMI.

Table 12: Keros types of Olfactory fossa among various studies.

Author	Country	Keros I (%)	Keros II (%)	Keros III (%)
Present study	India	36.96	**56.91**	5.97
Pawar A[1]	India	18.5	74.5	7
Original keros[2]	Germany	26.3	73.3	0.5
Shama AM[3]	Egypt	56.5	40.5	3.0
Kalpanoglu et al[4]	Turkey	13.4	76.1	10.5
Solares et al [5]	USA	83.1	15.0	2.0
Souza et al[6]	Brazil	26.3	73.3	0.5
Paber et al[7]	Philippine	81.08	17.7	0.5
Bista et al [8]	Nepal	86.0	12.0	2.0

Keros type II of OF (56.91%) was most common in our present study carried out in north Karnataka region of Karnataka, India, which was similar to the studies carried out in Maharashtra, India (74.5%)[1], Germany (73.3%)[2], Turkey (76.1%)[4] and Brazil (73.3%)[6]. Keros type I of OF was most common in Egypt (56.5%)[3], USA (83.1%)[5], Philippine (81.08%)[7] and Nepal (86%)[8] as shown in table 12.

Vinay kumar revealed 87% of cases of Keros type OF, 11% cases of keros type II OF & 2% of cases of Keros type III OF among 60 coronal CT scans in Trichy, Tamilnadu, India. CT Scan of Mean height of ethmoidal skull base varies between 3.7 mm to 15.4 mm with mean height of 10.05 mm at the level of anterior ethmoid artery canal. Low ethmoidal skull base was found in 2% of females.[9]

A study done by Satish Nair on 180 patients in Bangalore, Karnataka revealed 17.2% cases of type I keros, 77.2% cases of type II Keros & 5.6% cases of type III keros of OF.[10]

Tony J et al studied the incidence of Keros type I was 23.44%, type II was 70.83% and type III was 5.73%. Type III was common on the left side in a study done in New Delhi, India in among 32 dry human skulls using a hydroxyphilic siloxane based gel.[11]

Basak et al studied CT scans of 64 children and found most common Keros type II OF (53%) when compared to other types of OF. Keros type III was 38% and Keros type I was 9% .[12]

Jang et al studied 205 predominantly adult patients CT scan and noticed that Keros type II was most common (69.5%), followed by type I Keros (53.8%). Type III Keros was not found in this study.[13]

Anderhuber et al studied CT scans of children aged between zero and fourteen years. Type II was most common (70.6%). Type I Keros was 14.2% and Type II was 15.2%.[14]

Souza et al studied specifically 200 CT scans of adult patients and observed that the Keros type II olfactory fossa was most common (73.3%), followed by Keros type I OF (26.2%) and Keros type III OF (0.5%).[6]

Table 13: Comparison of width of Olfactory fossa on both sides among various studies.

Width of olfactory fossa	Right side Mean(in mm)	Left side Mean(in mm)
Present study	**5.08**	**4.76**
Tony GJ[11]	0.44	0.39
Daniel HC[12]	4.57	4.49
Savvateeva DM[13]	0.96	0.89

The average width of OF was 0.44mm on right side and 0.39mm on left side in a study done in New Delhi, India among 32 dry skulls using a hydroxyphilic siloxane based gel as shown in table 13.[11]

The average width of OF was 4.57mm on right side and 4.49mm on left side in a study done in USA on 31 human skull specimens by Daniel HC as shown in table 13.[12]

The average width of OF was 0.96mm on right side and 0.89mm on left side in a study done by Savvateeva DM on 111 patients by using digital volume tomography as shown in table 13.[13]

The width of olfactory fossa increases from frontal to the occipital end evenly. The mean width of OF was 3.8 mm on right side and 3.6 mm on left side below the crista galli. The width of OF was 5.2 mm on the right side and 5.1 mm on the left side in the posterior one third of OF. [14]

Table 14: Comparison of angle of Olfactory fossa on both sides among various studies.

Angle of olfactory fossa	Right side Mean(^{0})	Left side Mean(^{0})
Present study	**108.30**	**109.78**
Tony GJ[11]	130.58	128.74
Elwany[15]	159.42	153.26

The mean angle of OF was $130.58^0$and 128.74^0on right and left sides respectively in a study done byTony GJ[11] as shown in table 14.

The mean angle of OF was $159.42^0$and 153.26^0on right and left sides respectively in a study done byElwany[15] as shown in table 14.

Luigi maione et al observed angle of LLCP in 37 kallmann syndrome patients and compared with the non congenital hypogonadotropic hypogonadism patients in France. Significant wider angles of LLCP was observed in Kallmann syndrome.[16]

Table 15: Comparison of thickness of LLCP among various studies.

Thickness of LLCP	Mean(mm)
Present study	**1.22**
Keast A[17]	0.2-0.05

The mean thickness of LLCP was 1.22mm in our present study. Keast A showed that the mean thickness of LLCP was ranging from 0.2-0.05mm[17]as shown in table 15.

Table 16: Comparison of length of Cribriform Plate among various studies.

Length of CP	Mean(mm)
Present study	**20.66**
Daniel HC[12]	21.28
Elwany[15]	6.85
Savvateeva[13]	21.1

The mean length of CP was 20.66mm in our present study. The mean length of CP was 21.28mm, 6.85mm and 21.1mm in the studies carried out by Daniel HC[12] Elwany[15] and Savvateeva DM respectively[13] as shown in table 16.

Table 17: Comparison of BMI with depth of olfactory fossa among other studies.

BMI CASES		RIGHT SIDE OLFACTORY FOSSA	LEFT SIDE OLFACTORY FOSSA
80 BMI CASES PRESENT STUDY (> 25 bmi)	Pearson Correlation	0.246	0.229
	P VALUE	0.028	0.04
93 CASES CHRISTOPHER J. ITO[18]	Pearson Correlation	0.313	0.319
	P VALUE	0.002	0.002

Statistically significant positive correlation was found between both the sides of OF depth and BMI in our present study which was similar to study conducted by Christopher J Ito in 93 cases[18] as shown in table 17.

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SUMMARY& CONCLUSION

MORPHOLOGY OF OLFACTORY FOSSA AND
IT'S CORRELATION WITH BODY MASS INDEX
IN NORTH KARNATAKA REGION

CHAPTER 7.

SUMMARY AND CONCLUSION

SUMMARY

In the present study,

• Type II keros was most common when compared to other types of Keros depth of OF.

• Statistically significant differences were observed in the depth of OF, angulation of OF and CP length when compared between male and female patients.

• Significant differences were not observed in the width of OF and thickness of LLCP when compared between males and female patients.

• There was a linear correlation between BMI and OF depth as BMI increases, depth of OF shifts from type II to type III.

Conclusion:

This would help radiologists and endoscopic surgeons to approach these complicated regions of ethmoidal skull base which are difficult to access without distortion and without damaging other structures.

Research hypothesis that there is gender difference in the morphometry of olfactory fossa and there is correlation between body mass index and depth of olfactory fossa has been proved.

CLINICAL IMPLICATIONS

• Variations in FE, depth of OF, LLCP and course of anterior ethmoid artery are vulnerable during endoscopic sinus surgeries. It will also help Neurosurgeons for the management of Sellar and parasellar tumours, Optic nerve decompression, tumours arising from sensory epithelial olfactory cells which are difficult to access without distortion and without damaging other structure.

FUTURE PERSPECTIVES

To generalize the findings to Indian population, we need to conduct multicentric descriptive study.

PROFORMA FOR MASTER CHART

SL No	Age	Height of MERP		Height of CP -H		Depth Of OF		Keros Type of OF		SS	Width of OF		Thickness of LLCP		Angulation of LLCP		length of CP
		R	L	R	L	R	L	R	L		R	L	R	L	R	L	

ANNEXURES

MORPHOLOGY OF OLFACTORY FOSSA AND IT'S CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION

CHAPTER 8. ANNEXURES

CONSENT FORM

INFORMATION FOR PARTICIPANTS OF THE STUDY

Title of the project:

MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND ITS CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION

1. **Name, Designation, Address, Phone No. and Email ID of the Investigator:**

ANANDAGOUDA NAIKANUR ,
Lecturer, department of anatomy,
S. Nijalingappa medical college & HSK hospital,
Navanagar,
Bagalkot -587102
Phone: 9986272484
Email: goudas.naikanur@gmail.com

2. **Name of Guide with designation, Department, Phone No. and Email ID:**

DR. B. M. BANNUR
Professor & HOD
Department of anatomy
Shri B. M. Patil medical college, vijayapura
Phone: 7829082800
Email: bmbannur@gmail.com

Name of Co-guide with designation, Department, Phone No. and Email ID:

DR. SANJEEV. I .KOLAGI
Professor & HOD
Department of anatomy
S Nijalingappa medical college, bagalkot
Phone: 9731798355
Email: drsanjeevkolagi@yahoo.co.in

3. **Purpose/ Objectives of this project /study:**

PURPOSE

With regard to less data available on morphology of olfactory fossa in North Karnataka region, this study is undertaken to establish variations in the morphology of olfactory fossa on both sides in males and females and to find out the correlation between depth of the olfactory fossa and Body Mass Iindex by using Multidetector Computed Tomography. This would help radiologists and endoscopic surgeons to assess these vulnerable regions of ethmoidal skull base that are difficult to access without distortion and without damaging other structures.

OBJECTIVES

1) To establish the normative morphometry of olfactory fossa and its variations in right and left sides in both sexes.
2) To determine the sexual differences in the morphology of olfactory fossa on right and left sides.
3) To determine the correlation between olfactory fossa depth and body mass index (BMI).

4. Procedure/Methods of the study:

While taking the MDCT of paranasal sinuses, the patient will be informed and instructed about the procedure after the informed written consent. Axial CT images of 3mm thickness will be taken from Siemens - Somatom by using bone window. After exposure, the images will be reconstructed to 0.75mm thickness.

Comparative calculation of the thickness and angulation of the lateral lamella of the cribriform plate, depth and width of olfactory fossa at the level of infraorbital foramen, length of cribriform plate of both the sides in both sexes will be done by using RadiAnt DICOM Viewer. Olfactory fossa depth will be classified according to Keros classification i.e, type I – (0-3mm), type II-(4-7mm), type III- (8-16mm)

Side symmetry and relation of morphology of olfactory fossa in both sexes will be calculated by using Student 't' (unpaired) test. Correlation between the depth of olfactory fossa and BMI will be calculated by using student 't' (paired) test. The data will be considered statistically significant if p is less than 0.05.

5. Expected duration of the subject participation: 10 minutes

6 .Expected benefits from the research to the participant: The results of the present study will help us to understand the correlation between the depth of the olfactory fossa & BMI, which in-turn will help in management of skull base surgeries & endoscopic surgeries. This will also help in preventing the Spontaneous CSF leaks in higher BMI individuals.

7. Any risks expected from the study to the participant: None

8. Maintenance of confidentiality of records:

The study records will be kept confidential. patient personal identity will not be revealed in any publication or release of results. Study record will be kept indefinitely for analysis.

9. Provision of free treatment for research related injury:

Although the study procedure itself carries minimal risk, treatment of any unforeseeable event will be provided free of cost by the Institute to you.

10. **Compensation of the participants for disability or death resulting from such injury:** Compensation for any unforeseeable research-related injury or death resulting from such injury will be duly given to you through hospital insurance policy number 68040236170200000011

11. Freedom to withdraw from the study at any time during the study period without the loss of benefits that the participant would otherwise be entitled:

It is entirely your decision to participate in the study. If you want to discontinue from the study, you are free to leave without stating any reason. Your withdrawal would in no way result in SNMC withholding goodwill or normal medical care.

12. **Possible current and future uses of the biological material and of the data to be generated from the research and if the material is likely to be used for secondary purposes or would be shared with others, this should be mentioned**

    All the data and materials obtained from you will be used only for research purposes. It will not be used for secondary purposes nor will it be shared with others**.**

13. Address and telephone number of the Investigator and Co-Investigator/Guide:

ANANDAGOUDA NAIKANUR,
Lecturer, department of anatomy,
S. Nijalingappa medical college & HSK hospital,
Navanagar,
Bagalkot -587102
Phone: 9986272484
Email: goudas.naikanur@gmail.com

14.Contact details of Chairman of the IEC, SNMC for appeal against violation of rights.

Dr. S.L. Hoti,

Scientist G/ Director Grade Scientist

National Institute of Traditional Medicine - ICMR,

Belgaum- 590010

Phone No. 0831-2477477

Fax. 0831-2475479

CONSENT FORM

INFORMATION FOR PARTICIPANTS OF THE STUDY

B. V. V. Sangha's

S. NIJALINGAPPA MEDICAL COLLEGE & HSK HOSPITAL & RESEARCH CENTRE

BAGALKOT-587102

PROFORMA

NAME OF THE PATIENT: DATE:

AGE: IP/ OP NO:

SEX:

ADDRESS & CONTACT NUMBER:

DIAGNOSIS:

RESEARCH INFORMED CONSENT FORM

I have explained ________________________________ (Subject/Patient's/relevant guardian), the purpose of research, the procedures required and the possible risk and benefits to the best of my ability.

______________________ ______________________

Investigator Date

Confirm that ____ (PG guide/ Chief Researcher) has explained to me the purpose of research, the study procedure that I will undergo, and the possible risk and discomforts as well as benefits that I may experience. Therefore, I agree to give consent to participate as a subject in this research project (**MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND ITS CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION.**

______________________ ______________________

Subject /Parent /Guardian Date

______________________ ______________________

Witness to signature Date

INFORMED CONSENT FORM

Study Title: MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND ITS CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAK REGION
Study Number:
Subject's Full Name : Human Anatomy
Date of Birth/Age : 26-03-1985
Address : Department of Anatomy, S N Medical college, Bagalkot

1) I confirm that I have read the information in this form (or if has been read to me). I was free to ask any questions and they have been answered.

2) I have read and under stood this consent form and information provided to me.

3) I have been explained above the nature of the study.

4) I have been explained about duration of participation with number of participants.

5) I have been explained about procedures to be followed and about investigations, if any to be performed. I have been explained that I don't have to pay or bear the cost of procedure/investigations.

6) My rights and responsibilities have been explained to me by the investigators.

7) I have been adequately explained risks and discomforts associated with my participation in the study.

8) I have been explained about benefits of my participation in the study to myself, community and to medical profession.

9) If despite following the instructions I am physically harmed because of any substances or any procedures as stipulated in the study plan my treatment will be carried out free of cost at investigational site and the sponsor will bear all the expenses, If they are not covered by insurance agency or by Government program or any third party. I have had my questions, answered to my satisfaction

10) I have been explained about available alternative treatments.

11) I understand that my participation in the study is voluntary and I am free to withdraw at any time, without giving any reason and without my medical care or legal rights being affected.

12) I hereby give permission to the investigators to release information obtained from me as result of participation in the study to the sponsors, representatives of sponsors, regulatory authorities, Government agencies & ethics committee. I understand that they may inspect my original records.
However, I understand that my identity will not be revealed in any information released to third parties or published.

13) I agree not to restrict the use of any data or results that arise from the study provided such a use is only for scientific purpose (S).

I am exercising my free power of choice, hereby give my consent to be included as participant in the present study.

I agree to co-operate with investigator and I will inform him/her immediately. If I suffer unusual symptoms.

I am aware that if I have any questions during the study, I should contact at one of the address listed.

By signing this consent form I attest that this document has been clearly explained to me and understood by me.

Signature (or Thumb impression) of the Subject/Legally Acceptable Representative:_____________

Signatory's Name______________ Date_______________

Signature of the Investigator________ Date_______________

Study Investigator's Name: Anandagouda V Naikanur

Signature of the Witness ___________ Date_______________

Name of the Witness ______________________

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Multidetector computed tomographic morphology of olfactory fossa and its correlation with body mass index in north karnataka region

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CzsÀåAiÀÄ£À ಶೀರ್ಷಿಕೆ: **Multidetector Computed Tomographic morphology of olfactory fossa and its correlation with body mass index in north karnataka region**

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ವಿಳಾಸ:

1) ನಾನು ಈ ರೂಪದಲ್ಲಿ ಮಾಹಿತಿಯನ್ನು ಓದಿದ್ದೇನೆ (ಅಥವಾ ನನಗೆ N¢ w½¹gÀÄvÁÛgÉ) ಎಂದು ನಾನು ದೃಢೀಕರಿಸುತ್ತೇನೆ. ¸ÀA±ÉÆÃzsÀ£ÉUÉ ¸ÀA¨sÀzÀ¥ÀlÖ ¥Àæ±ÉßUÀ¼À£ÀÄß ¸ÀAPÉÆÃZÀ«®èzÉ PÉÃ¼À®Ä CªÀPÁ±À PÉÆnÖzÁÝgÉ.

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5) ಅನುಸರಿಸಬೇಕಾದ ಕಾರ್ಯವಿಧಾನಗಳ ಬಗ್ಗೆ ಮತ್ತು ತನಿಖೆಗಳ ಬಗ್ಗೆ, £À£ÀUÉ «ªÀj¹zÁÝgÉ ಕಾರ್ಯವಿಧಾನ / ತನಿಖೆಗಳ ವೆಚ್ಚವನ್ನು ನಾನು ಪಾವತಿಸಬೇಕಿಲ್ಲ ಅಥವಾ ಹೊರಡಿಸಬೇಕಾಗಿಲ್ಲ ಎಂದು £À£ÀUÉ «ªÀj¹zÁÝgÉ
6) ತನಿಖೆಗಾರರು ನನ್ನ ಹಕ್ಕುಗಳು ಮತ್ತು ಜವಾಬ್ದಾರಿಗಳನ್ನು ನನಗೆ «ªÀj¹zÁÝgÉ

7) ಅಧ್ಯಯನದ ನನ್ನ ಪಾಲ್ಗೊಳ್ಳುವಿಕೆಗೆ ಸಂಬಂಧಿಸಿದ ಅಪಾಯಗಳು ಮತ್ತು ತೊಂದರೆಗಳನ್ನು £À£ÀUÉ ಸಾಕಷ್ಟು «ªÀj¹zÁÝgÉ

8) ನನಗೆ, ಸಮುದಾಯ ಮತ್ತು ವೈದ್ಯಕೀಯ ವೃತ್ತಿಯಲ್ಲಿ ನನ್ನ ಪಾಲ್ಗೊಳ್ಳುವಿಕೆಯ ಪ್ರಯೋಜನಗಳ ಬಗ್ಗೆ £À£ÀUÉ «ªÀj¹zÁÝgÉ

9) ಸೂಚನೆಗಳನ್ನು ಅನುಸರಿಸುತ್ತಿದ್ದರೂ ನಾನು ಯಾವುದೇ ದೈಹಿಕ ಹಾನಿಗೊಳಗಾಗಿದ್ದರೂ ಅಧ್ಯಯನದ ಯೋಜನೆಯಲ್ಲಿ ಸೂಚಿಸಿದಂತೆ ಯಾವುದೇ ವಿಧಾನಗಳು ಅಥವಾ ಯಾವುದೇ ಕಾರ್ಯವಿಧಾನಗಳ ಕಾರಣದಿಂದಾಗಿ ನನ್ನ ಚಿಕಿತ್ಸೆಯನ್ನು

vÀ¤PÁ¢üPÁj CzsÀåAiÀÄ£À PÉÃAzÀæzÀ°è ಉಚಿತವಾಗಿ ನೀಡಲಾಗುವುದು ಮತ್ತು ಪ್ರಾಯೋಜಕರು ಎಲ್ಲಾ ಖರ್ಚುಗಳನ್ನು ಭರಿಸುತ್ತಾರೆ, ಅವುಗಳು ಒಳಗೊಂಡಿರದಿದ್ದರೆ ವಿಮಾ ಏಜೆನ್ಸಿ ಅಥವಾ ಸರ್ಕಾರಿ ಪ್ರೋಗ್ರಾಂ ಅಥವಾ ಯಾವುದೇ ಮೂರನೇ ವ್ಯಕ್ತಿಯಿಂದ. EzÀgÀ §UÉÎ EzÀÝ ನನ್ನ ಪ್ರಶ್ನೆಗಳನ್ನು ನನ್ನ ತೃಪ್ತಿಗೆ GvÀÛj¹zÀÝgÉ.

10) ಲಭ್ಯವಿರುವ ಪರ್ಯಾಯ ಚಿಕಿತ್ಸೆಗಳ ಬಗ್ಗೆ ನಾನು «ªÀj¹zÀÝgÉ

11) ಅಧ್ಯಯನದ ನನ್ನ ಪಾಲ್ಗೊಳ್ಳುವಿಕೆಯು ಸ್ವಯಂಪ್ರೇರಿತವಾಗಿರುವುದನ್ನು ನಾನು ಅರ್ಥಮಾಡಿಕೊಂಡಿದ್ದೇನೆ ಮತ್ತು ಯಾವುದೇ ಕಾರಣವನ್ನು ನೀಡದೆ ಮತ್ತು ನನ್ನ ವೈದ್ಯಕೀಯ ಆರೈಕೆ ಅಥವಾ ಕಾನೂನಿನ ಹಕ್ಕುಗಳು ಪರಿಣಾಮ ಬೀರದಿದ್ದರೂ ಯಾವುದೇ ಸಮಯದಲ್ಲಾದರೂ ಹಿಂಪಡೆಯಲು ನಾನು ಮುಕ್ತನಾಗಿರುತ್ತೇನೆ.

12) ಪ್ರಾಯೋಜಕರು, ನಿಯಂತ್ರಕ ಅಧಿಕಾರಿಗಳು, ಸರ್ಕಾರಿ ಏಜೆನ್ಸಿಗಳು ಮತ್ತು ನೈತಿಕ ಸಮಿತಿಯ ಪ್ರತಿನಿಧಿಗಳ ಅಧ್ಯಯನದಲ್ಲಿ ಪಾಲ್ಗೊಳ್ಳುವಿಕೆಯ ಪರಿಣಾಮವಾಗಿ ನನ್ನಿಂದ ಪಡೆದ ಮಾಹಿತಿಯನ್ನು ಬಿಡುಗಡೆ ಮಾಡಲು ನಾನು ಈ ಮೂಲಕ ತನಿಖೆದಾರರಿಗೆ ಅನುಮತಿ ನೀಡುತ್ತೇನೆ. ಅವರು ನನ್ನ ಮೂಲ ದಾಖಲೆಗಳನ್ನು ಪರೀಕ್ಷಿಸಬಹುದೆಂದು ನಾನು ಅರ್ಥಮಾಡಿಕೊಂಡಿದ್ದೇನೆ.
ಹೇಗಾದರೂ, ನನ್ನ ಗುರುತನ್ನು ಮೂರನೇ ವ್ಯಕ್ತಿಗಳಿಗೆ ಬಿಡುಗಡೆಯಾದ ಅಥವಾ ಪ್ರಕಟಿಸಿದ ಯಾವುದೇ ಮಾಹಿತಿಯಲ್ಲಿ ಬಹಿರಂಗಪಡಿಸಲಾಗುವುದಿಲ್ಲ ಎಂದು ನಾನು ಅರ್ಥಮಾಡಿಕೊಂಡಿದ್ದೇನೆ.

13) ಅಂತಹ ಬಳಕೆಯನ್ನು ಒದಗಿಸಿದ ಅಧ್ಯಯನದಿಂದ ಉದ್ಭವಿಸುವ ಯಾವುದೇ ಡೇಟಾ ಅಥವಾ ಫಲಿತಾಂಶಗಳ ಬಳಕೆಯನ್ನು ವೈಜ್ಞಾನಿಕ ಉದ್ದೇಶಕ್ಕಾಗಿ ಮಾತ್ರ G¥ÀAiÉÆÃV¸À®Ä ನಾನು ¤¨sÀðA¢¸ÀÄªÀ¢¯Áè.

£Á£ÀÄ £À£Àß EZÉÑÃAiÀÄÄAvÉÛ ಪ್ರಸ್ತುತದ ಅಧ್ಯಯನದಲ್ಲಿ ಪಾಲ್ಗೊಳ್ಳುವವನಾಗಿ ಸೇರಿಸಿಕೊಳ್ಳಲು ನನ್ನ ಒಪ್ಪಿಗೆ ನೀrgÀÄvÉÛ£É
ನಾನು ತನಿಖೆದಾರರೊಂದಿಗೆ ಸಹಕಾರ ಹೊಂದಲು ಒಪ್ಪುತ್ತೇನೆ ಮತ್ತು ಅಸಾಮಾನ್ಯ ಲಕ್ಷಣಗಳನ್ನು ಅನುಭವಿಸಿದರೆ ನಾನು ತಕ್ಷಣ CªÀjUÉ ತಿಳಿಸುತ್ತೇವೆ.
ಅಧ್ಯಯನದಲ್ಲಿ ನಾನು ಯಾವುದೇ ಪ್ರಶ್ನೆಗಳನ್ನು ಹೊಂದಿದ್ದರೆ, ನಾನು ಪಟ್ಟಿ ಮಾಡಲಾದ ವಿಳಾಸವೊಂದರಲ್ಲಿ ಸಂಪರ್ಕಿಸಬೇಕು ಎಂದು ನನಗೆ ತಿಳಿದಿದೆ.

ಈ ಸಮ್ಮತಿಯ ನಮೂನೆಯಲ್ಲಿ ಸಹಿ ಮಾಡುವ ಮೂಲಕ ಈ ಡಾಕ್ಯುಮೆಂಟ್ ಅನ್ನು ನನಗೆ ಸ್ಪಷ್ಟವಾಗಿ ವಿವರಿಸಲಾಗಿದೆ ಮತ್ತು ನನ್ನಿಂದ ಅರ್ಥೈಸಲಾಗಿದೆ ಎಂದು ನಾನು ದೃಢೀಕರಿಸುತ್ತೇನೆ.

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CzsÀåAiÀÄ£À vÀ¤PÁ¢üPÁj ಹೆಸರು: _ D£ÀAzÀUËqÀ ವಿ ನಾಯ್ಕನೂರ್__________

ಸಾಕ್ಷ್ಯದ ಸಹಿ _____________ ದಿನಾಂಕ__________________

ಸಾಕ್ಷಿ ಹೆಸರು ____________________________

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Annexure -I

PLAGIARISM VERIFICATION CERTIFICATE

1. Name of the Student: Mr. Anandagouda V Naikanur Reg No: 17PHD001

2. Title of the Thesis: MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND ITS CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION .

3. Department: ANATOMY

4. Name of the Guide & Designation: Dr,B M Bannur, Professor

5. Name of the Co Guide & Designation: Dr Sanjeev I Kolagi , Professor &HOD

The above thesis was verified for similarity detection. The report is as follows:

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The report is attached for the review by the Student and Guide.

The plagiarism report of the above thesis has been reviewed by the undersigned.

The similarity index is below accepted norms.

The similarity index is above accepted norms, because of following reasons:

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Signature of the Guide

Name & Designation

Professor
Dept. Of Anatomy
B.L.D.E. University's
Shri B.M. Patil Medical College,
Vijayapura

Signature of Co-Guide

Name & Designation

Professor & HOD
Dept. of Anatomy
S. N. Medical College
BAGALKOT

Signature of Student

Verified by (Signature)

Name & Designation

Librarian
B.L.D.E. Deemed to be University
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Vijayapur.

Ethical clearance certificates

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[Declared as Deemed-to-be-University u/s 3 of UGC Act, 1956 vide Government of India Notification No.F.9-37/2007-U.3(A)]

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SHRI. B. M. PATIL MEDICAL COLLEGE, HOSPITAL & RESEARCH CENTRE, VIJAYAPURA

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INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The ethical Committee of this University met on21st December 2018 at 11 a.m.to scrutinizes the Synopsis/ Research Projects of Post Graduate Student / Under Graduate Student Faculty members of this University / College from ethical clearance point of view. After scrutiny, the following original/ corrected and revised version Synopsys of the thesis/ research projects has been accorded ethical clearance.

Title. "MULTIDETECTOR COMPUTED TOMOGRAPHIC MORPHOLOGY OF OLFACTORY FOSSA AND ITS CORRELATION WITH BODY MASS INDEX IN NORTH KARNATAKA REGION"

Name of the Faculty member /PhD/PG/UG student. Mr.Anandagouda V Naikanur

Name of the Guide; DR. B. M. BANNUR Professor & HOD Department of Anatomy

Dr. Sharada Metgud

Chair person
IEC, BLDE (DU),
VIJAYAPURA

Dr.G.V.Kulkarni

Member Secretary
IEC, BLDE (DU),
VIJAYAPURA

MEMBER SECRETARY
Institutional Ethics Committee
BLDE (Deemed to be University)
Vijayapura-586103 Karnataka

Note:-Kindly send Quarterly progress report to the Member Secretary

Following documents were placed before ethical committee for Scrutinization.

- Copy of Synopsis/Research Projects
- Copy of inform consent form
  Any other relevant documents

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BLDE (DU): Phone: +918352-262770, Fax: +918352-263303 , Website: www.bldeuniversity.ac.in, E-mail:office@bldeuniversity.ac.in
College: Phone: +918352-262770, Fax: +918352-263019, E-mail: bmpmc.principal@bldeuniveristy.ac.in

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SNMC-INSTITUTIONAL ETHICS COMMITTEE ON HUMAN SUBJECTS RESEARCH
☏08354-235340 Fax: 08354-235360 Website: www.snmcbgk.in
Email: iechsrsnmcbgk@gmail.com

Office of the Institutional Ethics Committee

The Ethical Committee of SNMC reviewed the following documents:

1. Research Protocol entitled Genetic and Molecular Profiling of Multi detector Computed Tomographic Morphology Of Olfactory Fossa And Its Correlation With Body Mass Index In North Karnataka Region
2. Information sheet for participants of the study (Consent Form –I) and (Consent Form –II) of Multi detector Computed Tomographic Morphology Of Olfactory Fossa And Its Correlation With Body Mass Index In North Karnataka Region

NOTE: It is to be noted that neither PI nor any of the proposed study team members were present during the decision-making procedures of the Ethics Committee, and members who are independent of the Investigator, have voted/ provided opinion on the trial.

Discussion points:
After reviewing the documents submitted by the Principal Investigator, the Committee has decided to grant approval for conducting the above mentioned study.

You are requested to report to the Ethics Committee the Following:
1. Progress of the study at the end of 4 months.
2. Provide a report to the Ethics Committee on completion of the study.

The Ethics Committee of SNMC follows procedures that are in compliance with the requirements of ICH (International Conference on Harmonization) related to GCP (Good Clinical Practice), schedule Y and all other applicable Indian regulations.

If you have any Questions concerning the above, please feel free to contact the undersigned.
Thanks & Regards,

Vijayamahantesh

(Dr. Vijayamahantesh SN)
Member Secretary p 2/2

Member Secretary,
IEC
S. N. Medical College
BAGALKOT

Paper presentation certificates

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Publications

Original Article

Morphometry and Sexual Dimorphism of Olfactory Fossa in Relation To Crista Galli in North Karnataka Region – A Multidetector Computed Tomographic Study

Anandagouda V Naikanur[1], Balappa M Bannur[2], Sanjeev I Kolagi[3], Naseema Begum[4]

[1]Ph.D Scholar [2]Professor, Department of Anatomy, Shri B M Patil Medical College, Vijayapura, [3]Professor and Head, [4]Associate Professor, Department of Anatomy, S Nijalingappa Medical College, Bagalkot

Abstract

Background: The aim of this study was to establish the morphometry and sexual dimorphism of olfactory fossa and its correlation with the types of crista galli in North Karnataka region.

Method: Two hundred and twenty Multidetector computed tomographic (MDCT) scans were collected from North Karnataka region and analyzed by using RadiAnt DICOM Viewer. The depth and width of olfactory fossa, their side symmetry, types of crista galli and correlation between the depth of olfactory fossa with types of base of crista galli were calculated in both genders. Statistical analysis was done by using Student unpaired't' test.

Conclusion: Keros type II of olfactory fossa was most common in the present study. There was significant difference ($p<0.05$) in olfactory fossa depth when compared between right (mean=4.64mm) and left sides (mean=4.07mm) in females. There was no statistically significant difference found between the genderand the sides of depth and width of olfactory fossa. There was no statistically significant correlation found between the types of olfactory fossa and types of crista galli.The morphometry of olfactory fossa and crista galli would help neurosurgeons to assess these vulnerable regions of ethmoidal skull base in surgeries.

Key-words: *Cribriform plate, Crista galli, Keros classification, Olfactory fossa.*

Introduction

The Ethmoid bone lies in the anterior cranial fossa at the base of the cranial cavity. The cribriform plate, median perpendicular plate and two lateral labyrinths are the parts of the ethmoid bone. The orbital plate of the frontal bone and its roof joins with lateral lamellae of the cribriform plate (LLCP). [1]

Corresponding Author:
Dr. Sanjeev I Kolagi
MBBS, DLO,MD (Anatomy),
Professor and Head,Department of Anatomy,
S. Nijalingappa Medical College,
Bagalkot, Karnataka- 587102, India.
E-mail: sanjeevkolagi@gmail.com
Phone no: 9731798355.

The olfactory fossa is a depression in the anterior cranial fossa whose floor is formed by the cribriform plate. It is the most vulnerable site in the whole anterior skull base. It is medially bounded by crista galli and laterally by lateral lamella of the cribriform plate. [2]The depth of the olfactory fossa is determined by the height of the LLCP which is the thinnest area of the ethmoidal skull base. Thin LLCP and low ethmoidal skull base are the potential sites of injuries during endoscopic sinus surgeries.[3]Keros has classified the depth of olfactory fossa in to three types. Type I (1 to 3 mm), type II (4 to 7mm) and type III (8 to16 mm). [4]

Keros has also described the width and depth of olfactory fossa at different points and noted that type III Olfactory fossa exposes thin LLCP to injuries during surgeries. [2]

The width of olfactory fossa increases evenly from rostral to the occipital end. Measured below the wing of crista galli, the mean width is 3.8 mm on right side and 3.6 mm on left side. In the posterior one third, it is 5.2 mm on the right side and 5.1 mm on the left side at the rostral end. [5]

The Crista galli (CG) is a triangular median process projecting upwards from the centre of the cribriform plate. It has a thin and slightly curved posterior border and a much thicker and shorter anterior border. It is a compact bone, but can also be pneumatized in some individuals.[6]Thicker the crista galli, smaller the volume of olfactory fossa. Hajiioannou has classified the base position of crista galli into 3 types,

Type I= the base of the crista galli is located at the level of the cribriform plate.

Type II= less than 50% of the height of the crista galli is located below the level of the cribriform plate.

Type III= more than 50% of the height of the crista galli is located below the level of the cribriform plate.[7]

Aim

The aim of this study was to establish the morphometry and sexual dimorphism of olfactory fossa and its correlation with the types of crista galli in North Karnataka region.

Objectives

a) To determine the gender differences in depth and width of olfactory fossa on both the sides.

b) To determine the dimensions of pneumatisation of crista galli and Hajiioannou types of crista galli in both the genders.

c) To determine the correlation between olfactory fossa depth and Hajiioannou's classification of base of crista galli in both the genders.

Materials and Method

A prospective hospital based radiological study was done on two hundred and twenty Multidetector Computed Tomographic (MDCT) scans of the patients ofall the districts of North Karnataka region of Karnataka state, India, after institutional ethics committee clearance. The study was carried out from April 2018 to September 2019.

Normal Paranasal MDCT scans of patients above the age of 16 years belonging to both genders were included in the study.

MDCT scans of Patients below the age of 16 years and MDCT scans of patients with nasal or paranasal trauma, congenital abnormalities of face, tumours or conditions involving bone destruction and surgeries were excluded from the study. While taking the MDCT of paranasal sinuses, patients were informed and instructed about the procedure before obtaining informed written consent. Axial MDCT images of 3mm thickness were taken from CT scanner (Siemens Somatom) by using bone window.

Direct coronal scan showing the maximum depth of the olfactory fossa at the centre of infraorbital foramen was taken as reference point. Depth of the olfactory fossa was determined by the length of the lateral lamella of cribriform plate (CP). The height of CP point was subtracted from the height of medial ethmoidal roof point (MERP) to measure the length of the LLCP on both sides in both genders. Figure 1 shows Line A which represents a direct horizontal line connecting the middle of the inferior orbital foramina on both sides. Line B represents direct vertical line connecting line A and to the site of communication of fovea ethmoidalis and the lateral lamella of the cribriform plate of the ethmoid bone (LLCP). Line C was drawn as a direct vertical line connecting line A to the most lateral bony boundary of the cribriform plate of the ethmoid bone at its communication with the lateral lamella which will be CP height. The height of the ethmoid roof (h) was considered as the depth of the olfactory fossa. "h" was calculated as the result of subtraction of length of line C ("c") from the length of line B ("b") in millimeters (h =b-c). "h" will be representing the direct vertical height of the lateral lamella of the cribriform plate of the ethmoid bone.

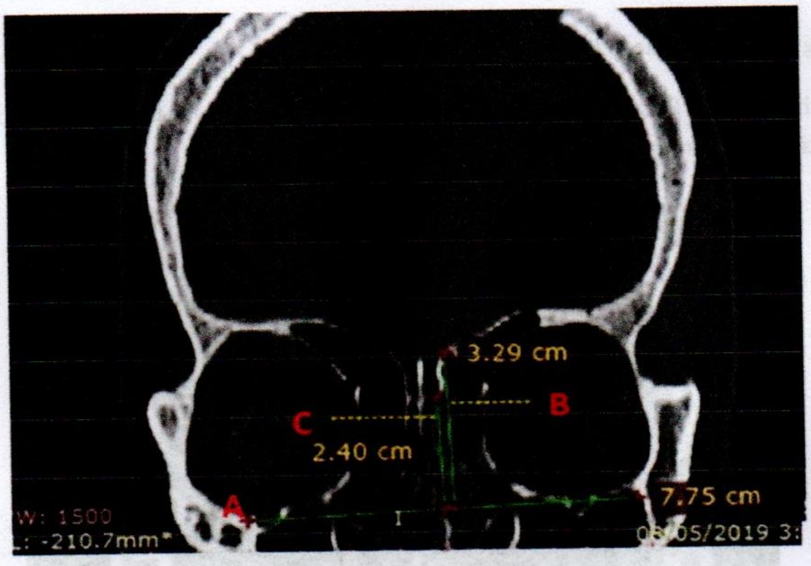

FIGURE 1: Showing coronal section of Multidetector computed tomographic scan of the patient at the level of infraorbital foramen.

A(77.5mm) -Line joining two infraorbital foramen,

B (32.9mm) -Line joining medial ethmoidal roof point to line A and

C (24mm) -Line joining cribriform plate to line A.

Olfactory fossa depth was classified according to Keros classification i.e, type I (0 to 3 mm), type II (4 to 7 mm), type III (8 to 16 mm)on both sides in males and females. The side symmetry of the types of depth of olfactory fossa was then compared in both genders as shown in figure 2.

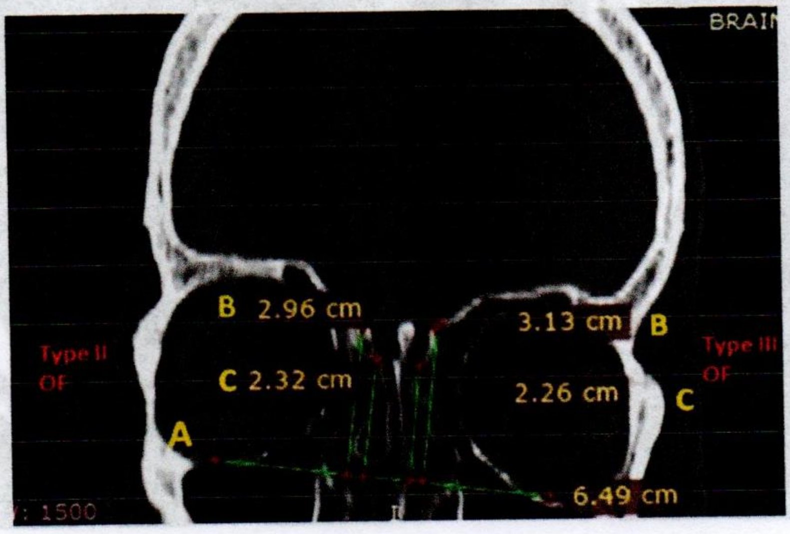

FIGURE 2: Types of depth of olfactory fossa in coronal section of MDCT scan on both the sides in the present study.

A- Line joining two infraorbital foramen,

B- Line joining medial ethmoidal roof point to line A and

C- line joining cribriform plate to line A.

The width of the olfactory fossa was measured from fovea ethmoidalis (fe) to the lateral margin of the crista galli at the level of centre of infraorbital foramina as shown in figure 3.

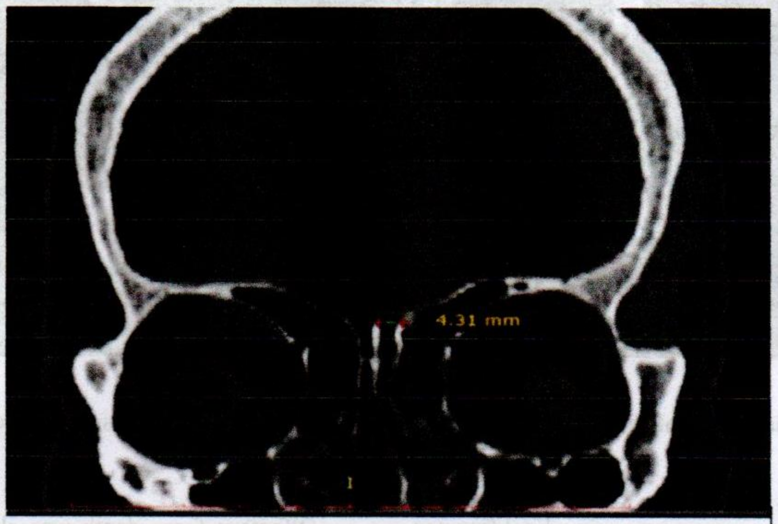

FIGURE 3: Measurement of width of left olfactory fossa in coronal section of MDCT scan of the patient.

The dimensions of the pneumatization of crista galli like anteroposterior and lateral to lateral diameter and types of base of crista galli according to Hajiioannous's classification (figure 4 & 5) were noted in both coronal and sagittal section of MDCT scans.

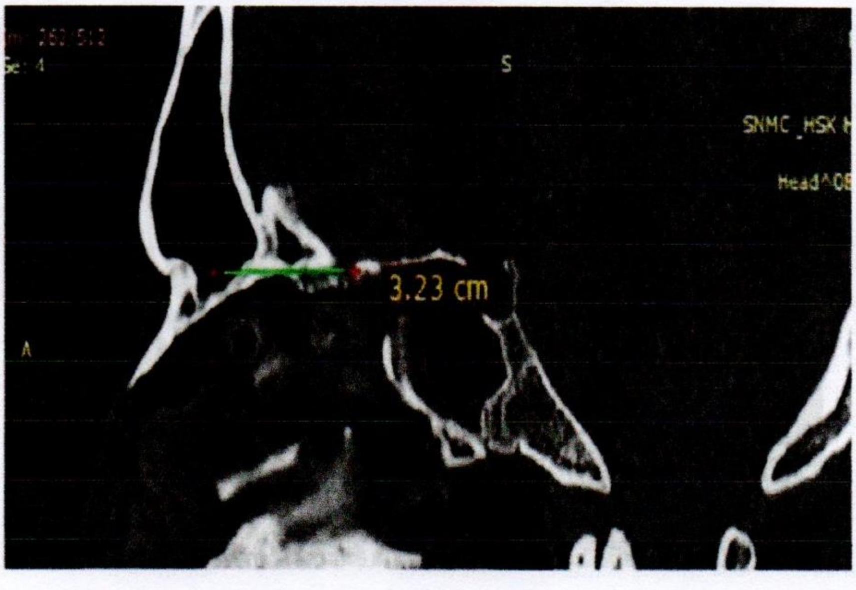

FIGURE 4: Sagittal section of MDCT scan of the patient with type I crista galli.

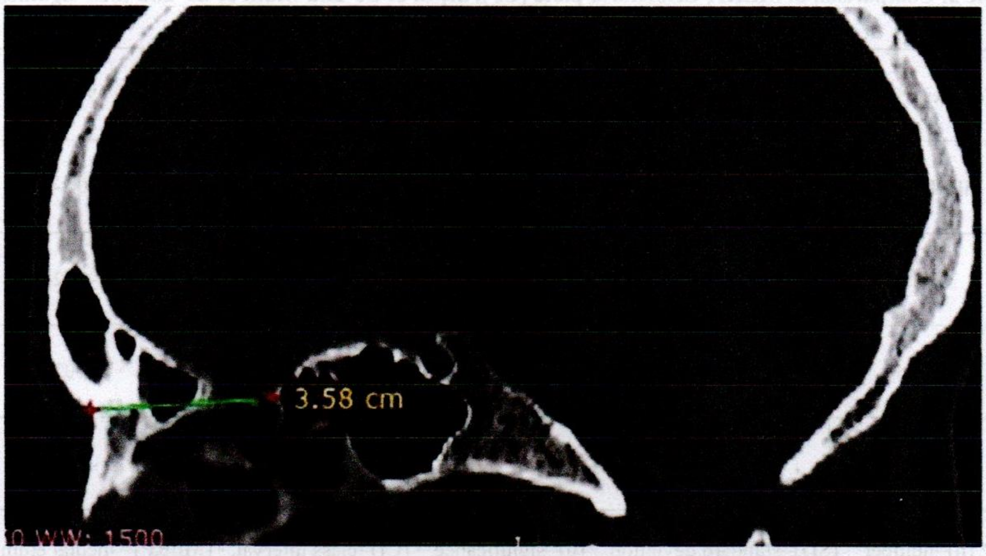

FIGURE 5: Sagittal section of MDCT scan of the patient with type II crista galli.

Results and Discussion

With regard to less data available in North Karnataka region, the present study was carried out to find out any correlation between the Keros types of olfactory fossa and types of crista galli.

Comparison of the mean±SD of MERP, CP, depth of OF, and width of OF, and their significance in the present study on both sides in both genders is shown in table 1,2 and 3.

Table 1: Comparison of MERP, Cribriform plate (CP), depth of OF, and width of OF and theirsignificance on both sides in males in the present study.

Males n * =131	Right side Mean±SD†	Left side Mean±SD	P‡ value	Significance	95% CI§
MERP‖ ht **	27.34±3.39	27.23±3.36	0.79	NS ††	-0.71-0.93
CP ht	22.4±3.12	22.79±3.02	0.3	NS	-1.13-0.35
OF depth	4.85±2.04	4.47±1.79	0.11	NS	-0.08-0.84
OF width	5.15±1.91	4.86±1.67	0.19	NS	-0.14-0.72

* (n)=number, † (SD)=standard deviation, ‡ (p)=significance, § (CI)=class interval, ‖ (MERP)= medial ethmoidal roof point, ** (ht)=height and †† (NS)=not significant

Table 2: Comparison of MERP, Cribriform plate (CP), depth of OF and width of OF and their significance on both sides in females in the present study

Females n*=89	Right side Mean±SD†	Left side Mean±SD	P‡ value	Significance	95% CI§
MERP ht **	25.43±3.29	25.3±2.99	0.78	NS ††	-0.8-1.06
CP ht	20.83±3.14	21.28±2.78	0.31	NS	-1.32-042
OF depth	4.64±2.09	4.07±1.77	0.05	S ‡‡	0.002-1.14
OF width	5.16±1.6	4.84±1.43	0.16	NS	-0.13-0.77

* (n)=number, † (SD)=standard deviation, ‡ (p)=significance, § (CI)=class interval, ‖ (MERP)= medial ethmoidal roof point, ** (ht)=height, †† (NS)=not significant and ‡‡ (S)= significant.

Table 3: Comparison of MERP, Cribriform plate (CP), depth of OF and width of OF and their significance on both sides in males and females in the present study

n*=220	Males (n=131) Mean±SD†	Females (n=89) Mean±SD	P‡value	Significance	95% CI§
MERP‖ ht **	27.34±3.39	25.43±3.29	0.000	S ††	1.009-2.824
	27.23±3.36	25.3±2.99	0.000	S	1.054-2.797
CP ht	22.4± 3.12	20.83±3.14	0.000	S	0.725-2.42
	22.79±3.02	21.28±2.78	0.000	NS‡‡	0.72-2.3
OF depth	4.85±2.04	4.64±2.09	0.46	NS	-0.35-0.76
	4.47±1.79	4.07±1.77	0.09	NS	-0.07-0.88
OF width	5.15±1.91	5.16±1.6	0.96	NS	0.49-0.47
	4.86±1.67	4.84±1.43	0.92	NS	-0.4-0.44

* (n)=number, † (SD)=standard deviation, ‡ (p)=significance, § (CI)=class interval, ‖(MERP)= medial ethmoidal roof point, ** (ht)=height, †† (S)= significant and ‡‡ (NS)=not significant

Among 220 MDCT scans, the mean MERP height was 26.57mm on the right side and 26.45mm on the left side. The cribriform plate height was 21.77mm on the right side and 21.28mm on the left side. The depth of the olfactory fossa was 4.76mm on the right side and 4.31 mm on the left side. The width of the olfactory fossa was 5.15mm on the right side and 4.85 mm on the left side.

Among 131 males, keros type I OF was found in 25 cases (19.08%) on the right side and 31 cases (23.66%) on the left side. Keros type II OF was found in 86 cases (65.64%) on the right side and 91 cases (69.46%) on the left side. Keros type III OF was found in 20 cases (15.26%) on the right side and 9 cases (6.87%) on the left side.

Among 89 females, keros type I OF was found in 23 cases (25.84%) on the right side and 31 cases (34.83%) on the left side. Keros type II OF was found in 54 cases (60.67%) on the right side and 51cases (57.3%) on the left side. Keros type III OF was found in 12 cases (13.48%) on the right side and 7 cases (7.86%) on the left side.

Keros type II of olfactory fossa was most common in the present study. There was significant difference ($p<0.05$) in olfactory fossa depth when compared between right (mean=4.64mm) and left sides (mean=4.07mm) in females. There was no statistically significant difference found between the gender and the sides of depth and width of olfactory fossa.

In the present study, symmetry of Olfactory Fossa depth was found in 94 cases (71.75%) in male patients and 54 cases (60.67%) in female patients. Asymmetry of Olfactory Fossa depth was found in 37 cases (28.24%) in male patients and 35 cases (39.32%) in female patients. There was no statistically significant difference found in the symmetry and asymmetry of olfactory fossa depth between the genders in the present study.

In the present study, type I Crista galli was found in 84 cases (64.12%) in male patients and 57 cases (64.02%) in female patients. Type II Crista galli was found in 47 cases (35.87%) in male patients and 32 cases (35.95%) in female patients. Type III Crista galli was not found in male and female patients. There was no statistically significant difference found between types of crista galli between the genders in the present study.

There was no correlation between the keros types of olfactory fossa and types of crista galli in the present study. Comparison of cases of keros type of olfactory fossa present in all types of crista galli in the present study on right side and left side in males and females is shown in chart 1and chart 2 respectively.

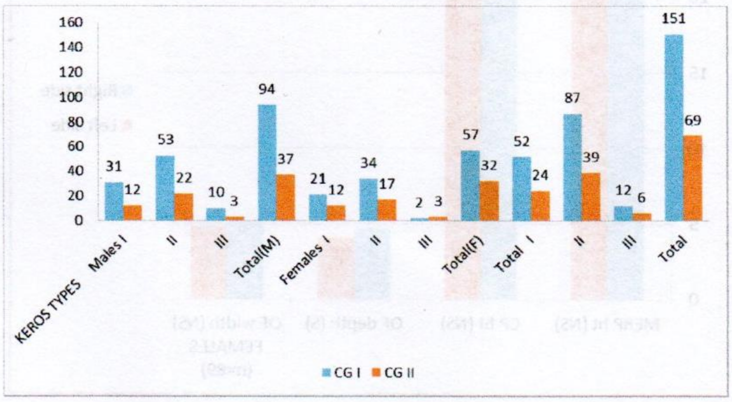

CHART 1 - Percentage of cases of keros types of olfactory fossa present in various types of crista galli in both genders on right side in the present study.

x axis = keros types I,II and III

Y axis= number of cases of Keros types I,II and III of OF in seen in CG types I,II and III

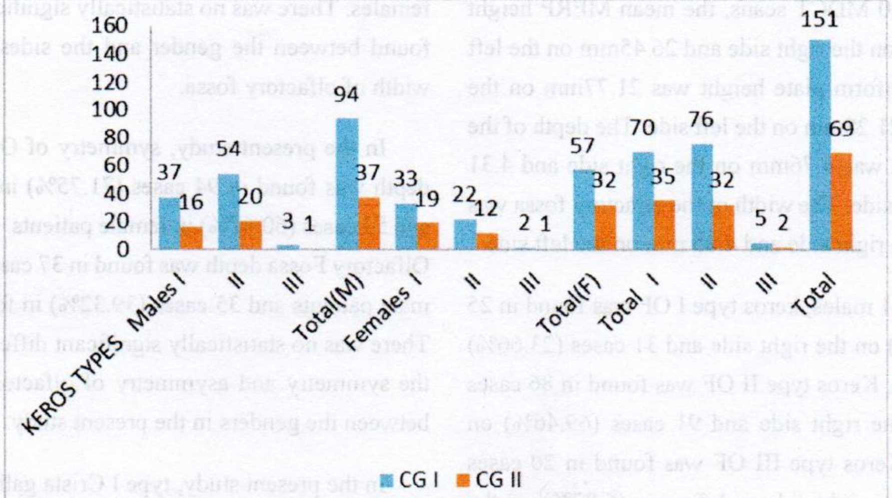

CHART 2 - Percentage of cases of keros types of olfactory fossa present in various types of crista galli in both genders on left side in the present study.

x axis = keros types I,II and III

Y axis= number of cases of Keros types I,II and III of OF in seen in CG types I,II and III.

There was statistically significant difference in olfactory fossa depth when compared between right and left sides in females as shown in table no 2 and chart 3. In males, there was no such difference as shown in table 1. Keros type II olfactory fossa was predominant (64%) among the cases and keros type III olfactory fossa was rare (10%) in the present study as shown in table no.4.

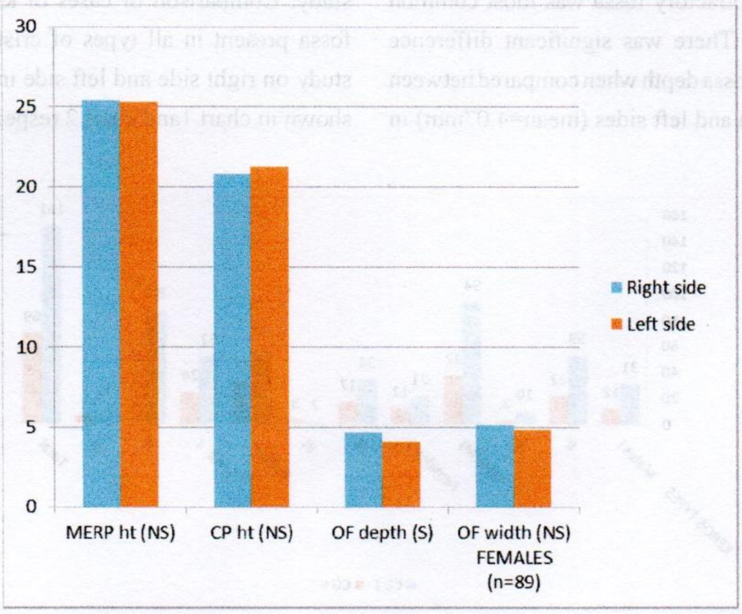

CHART 3- Comparison of MERP, CP, depth of OF and width of OF and their significance on both sides in females in the present study

n=number, CP= cribriform plate,MERP= medial ethmoidal roof point, , NS=not significant and S= significant.
x axis=MERP,CP,OF
Y axis= number of cases

Comparison of keros types of depth of olfactory fossa in the present study and in various studies is shown in table 4.

Table 4: Keros classification of Olfactory fossa among different studies.

Author	Country	Keros I (%)	Keros II (%)	Keros III (%)
Present study	India	24.99	64.08	10.00
Original keros 4	Germany	26.3	73.3	0.5
Shama AM 2	Egypt	56.5	40.5	3.0
Kalpanoglu et al 8	Turkey	13.4	76.1	10.5
Solares et al 9	USA	83.1	15.0	2.0
Souza et al 10	Brazil	26.3	73.3	0.5
Paber et al 11	Philippine	81.08	17.7	0.5
Bista et al 4	Nepal	86.0	12.0	2.0

Among 220 patients, the mean width of the olfactory fossa was 5.15 mm on right side and 4.85mm on left side in the present study. There was no significant difference in the width of olfactory fossa between the sides in the present study. The study done by Daniel h. Coelho et al revealed that the mean width of OF was 4.57mm on the right side and 4.49mm on the left side by Digital photography.[12]

In the present study, type I crista galli was found in 64.07% of cases, type II CG was found in 35.91% of cases and type III CG was not found. In the study done by Hajiioannou, type I crista galli was found in 28.3% of cases, type II CG was found in 63.6% of cases and type III CG was found in 8.1% of cases.

In the present study, the width, height and length of pneumatized Crista galli was 3.95mm, 9.3mm and 7.02mm respectively. In the study done by Gorazd Poje,[7] the width and length of pneumatized Crista galli was 5.1mm and 8.75mm respectively. In the study done by Ranko Mladina,[6] the width, height and length of pneumatized Crista galli was 3.75mm, 10.35mm and 7.8mm respectively.

Strengths and limitations of the study:

With regard to less data available in North Karnataka region, this study will help neurosurgeons and endoscopic surgeons to assess olfactory fossa during various skull base and endoscopic sinus surgeries.

This study was carried out only inNorth Karnataka region and there were limited number of patients during the study period. Only adult patients were included in this study.

Conclusion

The dangerous keros type III olfactory fossa was rare in the present study when compared to the most common keros type II olfactory fossa. There was statistically significant difference in olfactory fossa depth when compared between right and left sides in females. In males, there was no such difference. The width of olfactory fossa was not significant when compared between two sides in males and females. There was no statistically significant correlation found between the keros types of olfactory fossa and types of crista galli. The knowledge regarding the keros types of depth of olfactory fossa, width of olfactory fossa and types of crista galli will help the neurosurgeons to assess these vulnerable regions of ethmoidal skull base that are difficult to access during skull base surgeries.

Ethical Clearance - It was taken from Blde (deemed to be university) Shri B M Patil medical college, hospital and research centre, Vijayapura, Institutional ethical committee and SNMC-Institutional ethics committee on human Subjects research, Bagalkot.

Source of Funding - Self

Conflict of Interest - Nil

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Clinical relevance of thickness and angulation of Lateral Lamella of Cribriform Plate-A Multidetector Computed Tomographic study

Anandagouda Naikanur[1,2], Naseema begum[1], Sanjeev Kolagi[3], Balappa Bannur[2], Manjula Patil[4]

S. Nijalingappa Medical College, Bagalkot, Karnataka, India[1,3,4]
Shri B. M. Patil Medical College, BLDE (Deemed to be University), Vijayapura, Karnataka, India[2]

Keywords:
Angle, Lateral Lamellae of Cribriform Plate, Sexual Dimorphism, Thickness.

ABSTRACT

The morphometry and sexual dimorphism of lateral lamella of cribriform plate of the ethmoid bone provides assessement during various surgical procedures. This was prospective hospital based radiological study. Six hundred and forty four (644) Multidetector computed tomographic scans were collected from North Karnataka region and analyzed by using RadiAnt DICOM Viewer. The aim of this study was to determine the morphometry of the lateral lamella of cribriform plate of ethmoid bone. The thickness and angulation of lateral lamella of cribriform plate of olfactory fossa were calculated on both the sides in both genders. Statistical analysis was done by using Student unpaired't' test. There was statistically significant difference in the angle of lateral lamella of cribriform plate when compared between right side (mean=106.25°) and left side (mean=109.38°) in males. There was no such difference among females. Statistically significant difference was observed in the angle of lateral lamella of cribriform plate in male patients (mean=106.25°) when compared to female patients (mean=109.61°). The thickness of lateral lamella of cribriform plate was not significant when compared between two sides in males and females. Hence, these variations in the morphometry of the lateral lamella of cribriform plate of ethmoid bone will be of importance for the surgeons in Functional endoscopic sinus surgeries and anterior skull base surgeries.

1. INTRODUCTION

The lateral lamella of the cribriform plate (LLCP) is a part of the ethmoid bone in the anterior skull base. The LLCP joins laterally with the orbital plate of the frontal bone which protects the olfactory fossa [1]. LLCP forms the lateral boundary of the olfactory fossa. The lateral lamella of the cribriform plate is significantly shorter and less oblique in men than in women. The length of the lateral lamella was greater anteriorly than posteriorly in both sexes [2]. The two most common sites of skull-base injury associated with endoscopic sinus surgery are the lateral lamella of the cribriform plate and the posterior ethmoid roof near the anterior medial sphenoid wall [3]. The thin LLCP [4] offers less resistance to perforation which can lead to complications like direct penetration, trauma to dura matter, intracranial and intracerebral injuries during surgeries [5]. Hence, the morphometry of LLCP provides assessement during various surgical procedures like medial orbital wall decompression [6].

Very long and acutely angled lateral lamella predisposes patients to iatrogenic injury during surgeries. The angle of the LLCP was wider in many diseases like Kallmann syndrome. The angle of LLCP varies significantly in males and females according to the positions of the skull base [7]. Types of olfactory fossa with lesser angles are expected to be safer when compared to other types of olfactory fossa with greater angles during surgical procedures [8]. The level of the ethmoidal roof is affected by the angle of the LLCP which plays an important role in surgeries of anterior skull base [9].

Successful outcome of Endoscopic sinus surgeries with minimal complications can be achieved with prior knowledge of the endoscopic anatomy of anterior skull base and anatomical variations. Hence Radiological investigations and image-guided systems becomes an important tool which help the surgeons to perform safe and successful surgeries [10].

With regard to less data available in North Karnataka region, this study was undertaken to determine the morphometry of olfactory fossa in both genders which would help the neurosurgeons and endoscopic surgeons to assess the LLCP during various skull base and endoscopic sinus surgeries. The aim of this study was to establish the morphometry and sexual dimorphism of Lateral lamellae of cribriform plate in North Karnataka region. The objectives of our study was

(a) To determine the sexual dimorphism of thickness of LLCP on both sides.

(b) To determine the sexual dimorphism of angle of LLCP on both sides.

2. Materials and Method

Six hundred and forty four Multidetector Computed Tomographic (MDCT) scans of the patients from all the districts of North Karnataka region of Karnataka state, India were collected after institutional ethics committee clearance. This prospective hospital based radiological study was carried out from April 2018 to April 2021. Normal Paranasal MDCT scans of patients above the age of 16 years belonging to both genders were included in the study. MDCT scans of Patients below the age of 16 years and MDCT scans of patients with nasal or paranasal trauma, congenital abnormalities of face, tumours or conditions involving bone destruction and surgeries were excluded from the study. While taking the MDCT of paranasal sinuses, patients were informed and instructed about the procedure before obtaining informed written consent. Axial MDCT images of 3mm thickness were taken from CT scanner (Siemens Somatom) by using bone window.

The thickness of LLCP was measured in both the sides in both genders in direct coronal scan showing the maximum depth of the olfactory fossa at the centre of infraorbital foramen as shown in figure 1.

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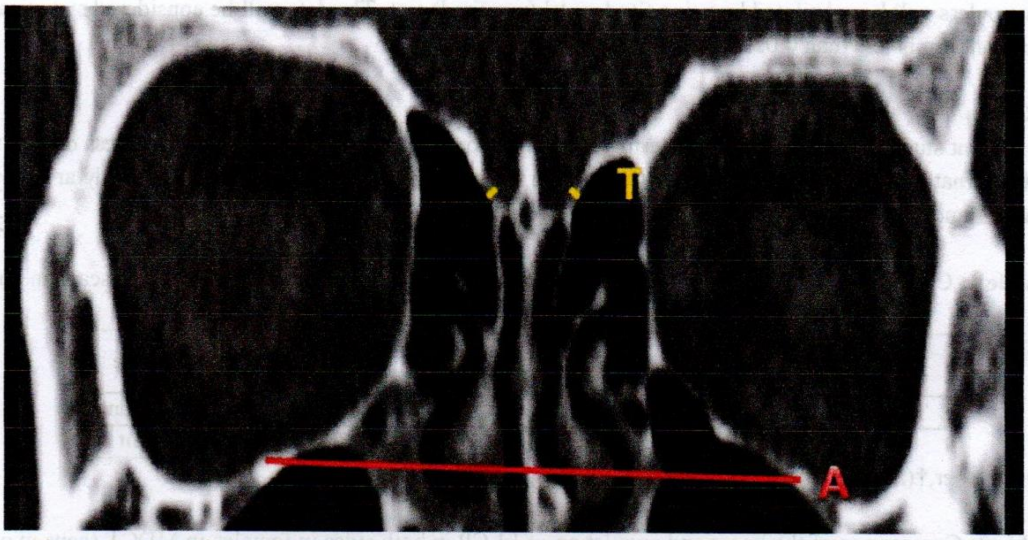

Figure 1: coronal scan showing the thickness of LLCP at the centre of the infraorbital foramen.
A=line at the level of infraorbital foramen
T=thickness of LLCP.

The angle at which LLCP joins the cribriform plate was measured in the direct coronal scan showing the maximum depth of the olfactory fossa at the centre of infraorbital foramen as shown in figure 2.

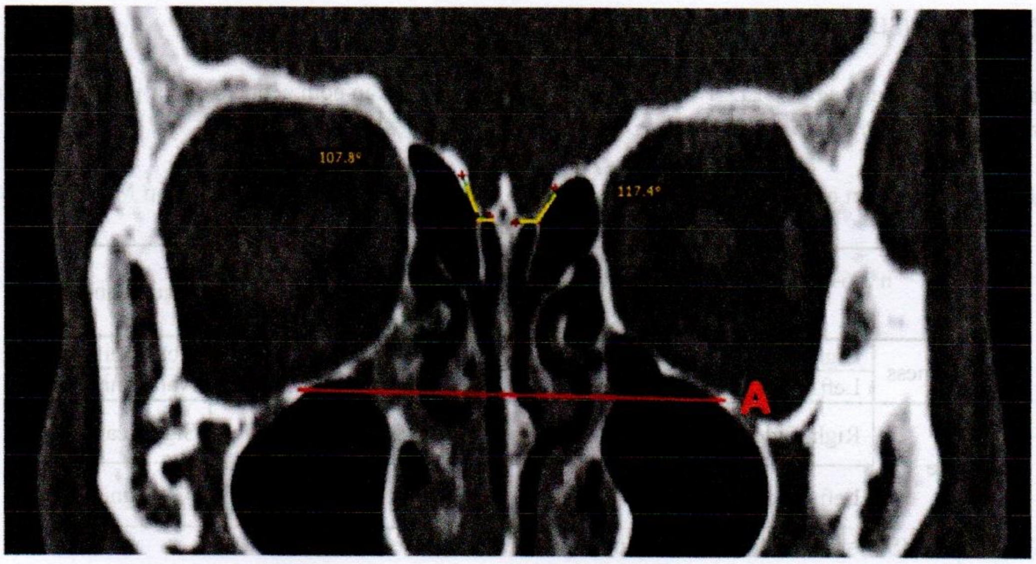

Figure 2: Coronal scan showing the angle of LLCP with cribriform plate at the centre of infraorbital foramen.
A=line at the level of infraorbital foramen. Yellow lines showing the measurement of angle of LLCP with cribriform plate of ethmoid bone on right and left sides.

Comparative calculation of the thickness and angulation of LLCP was done on both the sides in both genders by using RadiAnt DICOM Viewer. Comparison of the thickness and angulation of LLCP on both the sides in both genders will be calculated by using Student 't' (unpaired) test. The data will be considered statistically significant if p is less than 0.05.

3. Results

The present study was carried out to determine the morphometry of the LLCP as there were less data in the North Karnataka region. The angle of LLCP on both the sides in males and females in our study are shown in table 1 and 2 respectively.

Table 1: Comparison of thickness and angulation of LLCP in both sides in males in MDCT scans in our present study.

Males (n*=395)	Right side (Mean±SD†)	Left side (Mean±SD†)	P‡ value	Significance
Thickness	1.26±0.66mm	1.23±0.52mm	0.47	Not significant
Angle	106.25˚±20.35˚	109.38˚±16.81˚	0.018	Significant

*(n)=number,†(SD)=standard deviation and ‡(p)=significance value.

Table 2: Comparison of thickness and angulation of LLCP in both sides in females in MDCT scans in our present study.

Females n*=249	Right side Mean±SD†	Left side Mean±SD†	P‡ value	Significance
Thickness	1.21±0.56mm	1.22±0.53mm	0.8379	Not significant
Angle	109.61˚±19.50˚	109.99˚±18.63˚	0.8241	Not significant

*(n)=number, †(SD)=standard deviation and †(p)=significance value

Comparison of mean angle of LLCP and its p value of both the sides in both genders in our present study are shown in table 3 and 4.

Table 3: Comparison of thickness and angulation of LLCP in both sides in both genders in MDCT scans in our present study.

n*=644		Males (n*=395) Mean±SD†	Females (n*=249) Mean±SD†	P‡value	Significance
Thickness	Right Side	1.26±0.66mm	1.21±0.56mm	0.3219	Not significant
	Left Side	1.23±0.52mm	1.22±0.53mm	0.8136	Not significant
Angle	Right Side	106.25˚±20.35˚	109.61˚±19.50˚	0.03852	Significant
	Left Side	109.38˚±16.81˚	109.99˚±18.63˚	0.6674	Not significant

*(n)=number, †(SD)=standard deviation, ‡(p)=significance value

Table 4: Comparison of thickness and angulation of LLCP in both genders in MDCT scans in our present study.

n*=644	Males (n*=395) Mean±SD†	Females (n*=249) Mean±SD†	P‡ value	Significance
Thickness	1.21±0.56mm	1.22±0.53mm	0.8379	Not significant

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Angle	109.61˚±19.50˚	109.99˚±18.63˚	0.8241	Not significant

*(n)=number, †(SD)=standard deviation, ‡(p)=significance value.

4. Discussion

This morphometry of the LLCP will help the neurosurgeons and endoscopic surgeons to assess during various surgeries. Statistically significant difference (p=0.018) was observed in the angle of LLCP between two sides (right side angle=106.25˚ & left side angle=109.38˚) in male patients when compared to female patients. In females, there was no statistical difference in the angle of LLCP between both the sides as shown in table 2.

Significant difference (p=0.03) in the angle of LLCP was also observed on the right side (mean angle in male patients=106.25˚ and mean angle in female patients =109.61˚) when compared between males and female patients as shown in table 3.

Highly significant wider angles of LLCP in Kallmann syndrome was observed when compared to non congenital hypogonadotropic hypogonadism patients among 37 Kallmann syndrome patients in France [11]. Significant difference was observed between lateral lamella angulation in men and women in a study done in 300 patients in Egypt [2].

Patients with Keros type III olfactory fossa having an angle of LLCP with 107˚ are safer when compared with keros type I and type II olfactory fossa with 116˚ and 131˚ respectively on 141 patients [8].

The angle of the lateral lamella was 63.1 ±17.8˚ anteriorly and 39.1 ±17.9˚ posteriorly ($p < 0.05$) [7].

No significant difference was observed in the angulation of the LLCP on left and right sides ($p > 0.05$) [12]. The thickness of LLCP on both the sides in males and in females is shown in table 1 and 2 respectively. Comparison of mean thickness of LLCP and its p value of both the sides in both genders are shown in table 3 and 4. There were no significant differences observed in the thickness of LLCP between both the sides and in between the genders.

The thickness of LLCP can vary from 0.2 to 0.05 mm [13].

This study will help neurosurgeons and endoscopic surgeons to assess LLCP during various skull base and endoscopic sinus surgeries as there were less data in North Karnataka region.

Only adult patients were included in the present study. This study was carried out only in patients of North Karnataka region during the study period.

5. Conclusion

The thin LLCP offers less resistance to perforation which can lead to complications during various surgical procedures. Statistically significant difference (p=0.018) was observed in the angle of LLCP between two sides (angle=106.25˚ on right side & angle =109.38˚ on left side) in male patients. In females, there was no such difference. Significant difference (p=0.03) in the angle of LLCP was also observed on the right side (angle= 106.25˚ in male patients and angle = 109.61˚ in female patients) when compared between males and female patients.

The thickness of LLCP was not significant when compared between two sides in males and females. Hence, the morphometry of LLCP provides assessement in skull base surgeries.

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