CADAVER DISSECTION AND CT CORRELATION OF LACRIMAL SAC AND NASOLACRIMAL DUCT: A PRELUDE TO ENDOSCOPIC DACRYOCYSTORHINOSTOMY

A

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CERTIFICATE

This is to certify that the dissertation entitled **'Cadaver dissection and CT correlation of lacrimal sac and nasolacrimal duct: a prelude to endoscopic dacryocystorhinostomy'** is a bonafide original work of **Dr Amit Kumar Tyagi,** submitted in partial fulfilment of the rules and regulations for the MS Branch IV, Otorhinolaryngology examination of The Tamil Nadu Dr. M.G.R Medical University to be held in April 2012.

Dr Achamma Balraj
Professor and Head
Department of ENT
Christian Medical College,
Vellore

CERTIFICATE

This is to certify that the dissertation entitled **'Cadaver dissection and CT correlation of lacrimal sac and nasolacrimal duct: a prelude to endoscopic dacryocystorhinostomy'** is a bonafide original work of **Dr Amit Kumar Tyagi,** carried out under my guidance, in partial fulfilment of the rules and regulations for the MS Branch IV, Otorhinolaryngology examination of The Tamil Nadu Dr. M.G.R Medical University to be held in April 2012.

Dr Mary Kurien
Professor
Department of ENT,
Christian Medical College,
Vellore

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ABSTRACT

CADAVER DISSECTION AND CT CORRELATION OF LACRIMAL SAC AND NASOLACRIMAL DUCT: A PRELUDE TO ENDOSCOPIC DACRYOCYSTORHINOSTOMY

Objectives and aims of study:

To measure the distances of surgically important landmarks from relevant structures by cadaveric dissection and CT scan, as a means for assisting the surgeon to grasp three-dimensional anatomy and as a prelude to endoscopic dacryocystorhinostomy.

Design: This was a descriptive study (Cadaver dissection/case series) in which data collection was done by measurement of anatomical landmarks in CT scan and cadaver sagittal head sections.

Participants: Ten adult cadaver's head sections (10 right and 10 left sagittally sectioned specimens) fixed with 10% formaldehyde solution

Setting: Anatomy, ENT and Radiodiagnosis department of a tertiary hospital.

Results: Maxillary line was clearly identified in 15 (75%) and not clear in five (25%) cadavers. The distance between the anterior nasal spine to axilla and anterior nasal spine to genu was noted as an average of 34.89 mm (23.64-44.40) and of 28.15 mm (19.98-37.21) respectively and these measurements also showed positive correlation with corresponding CT measurements. The lacrimomaxillary suture was seen posterior to maxillary line in nine (45%); at maxillary line in eight (40%) and anterior to maxillary line in three (15%) of the cadavers. Maxillary line overlapped the

lacrimal sac in 95% cadavers. Thickness of lacrimal bone was found to be an average of 0.25 mm. The distance between the inferior edge of lacrimal sac and inferior turbinate was an average of 7.90 mm. The anteroposterior diameter of lacrimal sac was an average of 7.35 mm. The length of lacrimal sac was an average of 11.72 mm and showed positive correlation with CT scan measurements. The distance between fornix (superior end) of lacrimal sac and axilla of middle turbinate was of 8.88 mm and showed positive correlation with CT scan measurements. More than half of the lacrimal sac was above the axilla in 60% and less than half above the axilla in 40 % of cadavers in our study (seen both in dissection and CT scans). The length of nasolacrimal duct (NLD) was an average of 10.27 mm in length and showed positive correlation with CT scan measurements. NLD was about 4.04 mm anterior to maxillary sinus ostium. Agger nasi was noted in 16 cases (80%).

Conclusions

Incision performed anterior to the maxillary line and anterior to genu of middle turbinate with 8-9 mm above axilla could be sufficient to expose the lacrimal sac. Maxillary line, Mpoint and axilla are three important landmarks in localization of sac. M point can be used as an inferior limit of surgical exposure of lacrimal sac. Preoperative endoscopic evaluation for the presence of aggar nasi is mandatory in all cases prior to endoscopic dacryocystorhinostomy. CT scan appears to be also useful in measuring length of lacrimal sac and nasolacrimal duct.

Key words: Dacryocystorhinostomy; Cadaver dissection; Computed tomography; Endoscopy; Lacrimal sac; Nasolacrimal duct;

INTRODUCTION

Endoscopic Dacryocystorhinostomy (Endo-DCR) enables improved visualization, without any risk of creating a lesion in the medial palpebral ligament and orbicularis oculi. This procedure does not require an external incision and thus presents a cosmetic advantage. There is no risk of angular vein damage and this procedure spares the pumping function of the nasolacrimal system, and promotes faster healing. The main difficulty of endoscopic dacryocystorhinostomy is the determination of the place of the mucosal incision and lacrimal osteotomy. Intranasal surface anatomy is fundamental to the technique of endoscopic dacryocystorhinostomy.(1) The comprehensive knowledge of surgeons in regard to topographic anatomy and the lateral wall is fundamental to the successful performance of dacryocystorhinostomy. The recognition of the anatomical relationship between the lacrimal sac and other parts nearby enables an easier operation and helps to obtain more reliable results.(2)

Endonasal landmarks have been set to establish a correct approach. The landmarks placed on the lateral nasal wall of the nasal cavity are the **axilla** of the middle turbinate (the most anterior part of the middle turbinate, where it adheres to the lateral nasal wall), the **maxillary line** (the protrusion that lies as a curved line from the axilla of the middle turbinate to the inferior turbinate), the **ethmoidal bulla**, and the **uncinate process**.(1) The maxillary line and axilla of the middle turbinate are the most frequently used anatomical landmarks. However, not many cadaver studies have been performed on these landmarks and their relationship to lateral nasal wall and lacrimal sac. Specifically, in case of the anatomical variations, the performance of a mucosal incision and osteotomy in a safer area is essential for successful surgery. Although surgeons perform same incisions,

osteotomies, and operations, these procedures may be unsuccessful due to anatomical differences in patients. (1)

This study was undertaken to review the anatomy of the nasolacrimal apparatus in relation to the lateral nasal wall and to measure the distances of surgically important landmarks by cadaveric dissection and CT scans as a means for assisting the surgeon to grasp three-dimensional anatomy and for performing Endoscopic-DCR. This is the first correlational study between cadaveric dissection and CT scan of the nasolacrimal apparatus.

AIMS & OBJECTIVES

1. To measure the distances of surgically important landmarks from relevant structures as a means for assisting the surgeon to grasp three-dimensional anatomy and as a prelude to endoscopic dacryocystorhinostomy.

2. To correlate cadaveric dissection and CT scan measurements.

3. To evaluate the role of CT scan in endoscopic dacrocystorhinostomy.

4. To optimize the approach to the lacrimal sac during endoscopic dacrocystorhinostomy.

REVIEW OF LITERATURE

Dacryocystorhinostomy (DCR) is performed to divert lacrimal drainage into the nose through an osteotomy at the level of the lacrimal bone, done either through an external or endonasal approach. External DCR was originally described in 1904 by Toti, who resected the lacrimal sac mucosa, bone, and nasal mucosa through an external skin incision.(3) This technique was modified by Dupuy-Dutemps and Bourguet, who sutured the mucosal flaps, thus forming an epithelium-lined fistula. Several case series have estimated the success rate of external DCR to be between 85% and 95%. (4)(5)(6) However, the skin incision and injury of the medial canthal ligaments with resultant lacrimal pump dysfunction have been reported as disadvantages.(3)

Endonasal dacryocystorhinostomy was first proposed by Caldwell in 1893. Caldwell used an electric burr to create a middle meatal osteotomy in the area marked by a metal probe. West modified it in 1914. He did a window osteotomy by removal of the lacrimal bone and the superior maxilla to access the nasolacrimal duct.(3) However, the popularity of endonasal DCR did not increase until the 1970s and 1980s. With the introduction of operating microscopes, rigid and semi-rigid nasal endoscopes, and fiberoptic delivery systems, physicians were able to evaluate intranasal anatomy. Prior to these advances, the endonasal technique was limited due to poor visualization and illumination and bleeding of the nasal mucosa.(3) Rice demonstrated in cadaver studies that endoscopy was a viable option in DCR.(7) McDonough and Meiring published the first clinical study of endoscopic DCR in 1989.(8) The reported success rate for endoscopic endonasal DCR ranges from 63% to 90%. (4)

In 1990 Massaro et al did a cadaveric study of endonasal laser-assisted DCR using the argon blue-green laser for bone removal.(9) Levin and Stormogipson performed endocanalicular laser-assisted DCR in cadaveric specimens.(10) Gonnering et al introduced the first clinical trial of endonasal laser-assisted DCR. They removed bone by the carbon dioxide (CO2) and potassium titanyl phosphate (KTP)/neodymium-yttrium-garnet (Nd:YAG) laser.(11) Javate et al in 1995 introduced endoscopic DCR with a radiofrequency unit. They incised the nasal mucosa and bone with radiofrequency unit which simultaneously cuts and coagulates with mild heat damage. They also used a Kerrison rongeur to enlarge the bony osteomy, and mitomycin C and silicone stents to prevent restenosis of the ostium.(12) Clinical studies of endocanalicular laser-assisted DCR (Nd:YAG) was reported by Pearlman and Michalos (13) and and Fay(14). They reported success rates of 91% and 84% respectively. Familiarity with the Nd: YAG laser is a popular choice as surgeons are familiar with it in bony ablation in sinus surgery and it also provides excellent hemostasis in the contact mode. (14)

ANATOMY OF LACRIMAL SYSTEM

EMBRYOLOGY:

The formation of the lacrimal drainage system begins at the 4th fetal week. The maxillary and frontal prominences appear and then a groove is formed between them. Ectoderm forms a cord inside the groove extending from the nasal cavity to the medial canthus at 5th week. The upper portion of the primitive cord forms the lacrimal sac. Cords of ectoderm invaginate from the lower and upper lid margins and forms the canaliculi at 10th week. Canalization of the ectodermal cord begins at the 4th month. Canalization progresses upward and downward until the end of the 7^{th} month to form complete

opening of the puncta . From the 8th month onwards, inferior portion of the nasolacrimal duct opens into the inferior nasal meatus. Approximately 70% of the newborns have imperforate membranes of Hasner. They usually open within the first month but the process may take longer. Malformations of the lacrimal drainage system may occur anytime during the development of the fetus and are more severe if it occurs in the earlier stages.(15)

ANATOMY:

Lacrimal apparatus: The lacrimal excretory system consists of the main lacrimal gland, 10 to 12 secretory ducts located within the superotemporal conjunctival fornix, and accessory glands (of Krause and Wolfring) located in the conjunctival fornix and in the palpebral conjunctiva. Whitnall's ligament provides support and prevents prolapse of the lacrimal gland .The lacrimal apparatus provides for egress of tears via puncta located at the medial aspect of the eyelids.(16) The lacrimal drainage system consists of the lacrimal puncta, inferior and superior canaliculi, common canaliculus, lacrimal sac, and nasolacrimal duct (**Fig. 1**(17) **and 2**(18)). It is divided into upper and lower portions, but it is only one embryological and histological structure.(18) Each punctum opens into an avascular mound of fibrous tissue called the lacrimal papilla. The punctal opening, approximately 0.3 mm in diameter, leads to a canaliculus. Canaliculus extends 2 mm vertically and then it turns 90 degrees toward the medial canthus (**Fig. 1 and 2**). It travels through the orbicularis muscle for 8 mm to join lacrimal sac at an acute angle. The inferior and superior canaliculi coalesce to form a common canaliculus in 90% to 94% of individuals before joining the lacrimal sac. The medial aspect of the common canaliculus contains the valve of Rosenmuller. Valve of Rosenmuller prevents tear reflux.(16) The common canaliculus and lacrimal sac are placed between the anterior and posterior limbs of the medial canthal ligament. The superficial head attaches to anterior lacrimal crest and

the deep head (Horner's muscle), to the posterior lacrimal crest.(18) The lacrimal sac averages 12 to 15 mm in height. It usually extends 3 to 5 mm superior to the medial canthal ligament. It is immediately external to the orbit, within the lacrimal fossa, an indentation formed by the frontal process of the maxilla anteriorly and the thinner lacrimal bone posteriorly. This bony fossa is bordered by the anterior and posterior lacrimal crests. In particular, the frontal process of the maxilla is thicker than the lacrimal bone and can provide a challenging step for a sufficient osteotomy. The lacrimal sac is located in the lacrimal fossa between the superficial and deep fibers of the orbicularis muscle and between the anterior and posterior fibers of the medial canthal tendon. Approximately 1/3 of the lacrimal sac lies above the level of the medial canthal tendon.(16) The fundus of lacrimal sac is situated an average of 8.8 mm above the insertion of the middle turbinate.(2) The rounded lower end of the lacrimal sac is continuous inferiorly with the nasolacrimal duct.(19) The duct travels within the bony nasolacrimal canal for approximately 11 mm and continues 2 to 5 mm intranasally into the inferior meatus.(20) It opens approximately 15 mm above the nasal floor and 4 to 6 mm posterior to the head of the inferior turbinate. The duct is directed posteriorly and slightly laterally towards opening. A mucosal fold, the valve of Hasner, is usually present at the nasal opening.(16) The upper and lower canaliculi are lined by pseudostratified and stratified columnar epithelium. These are surrounded by a dense ring of connective tissue, muscle fibers of the lacrimal portion of the orbicularis oculi muscle (Horner's muscle).(18) The lacrimal sac and the nasolacrimal duct are lined by a double layered epithelium and are surrounded by vascular system comparable to a cavernous body. The double-layered epithelium is composed of a superficial columnar layer and a deep flattened layer of basal cells. Both layers sometimes appear as a pseudostratified epithelium. Most epithelial cells are lined by microvilli. Lower part of the nasolacrimal duct is commonly lined by kinocilia.(18)

Mechanisms of Tear Drainage

Drainage of tears involves a number of different mechanisms.(18)

1. Active lacrimal pump mechanism aided by contraction of the lacrimal portion of the orbicularis muscle

2. Distension of the lacrimal sac by the action of the lacrimal portion of the orbicularis muscle

3. Epithelial secretion products (mucins and TFF peptides) of the epithelium of the lacrimal sac and nasolacrimal duct

4. "Wringing-out" mechanism governed by a system of helically arranged fibrillar structures

5. Opening and closing of the lumen of the lacrimal passage effected by the bulging and subsiding of the cavernous body

6. Capillarity

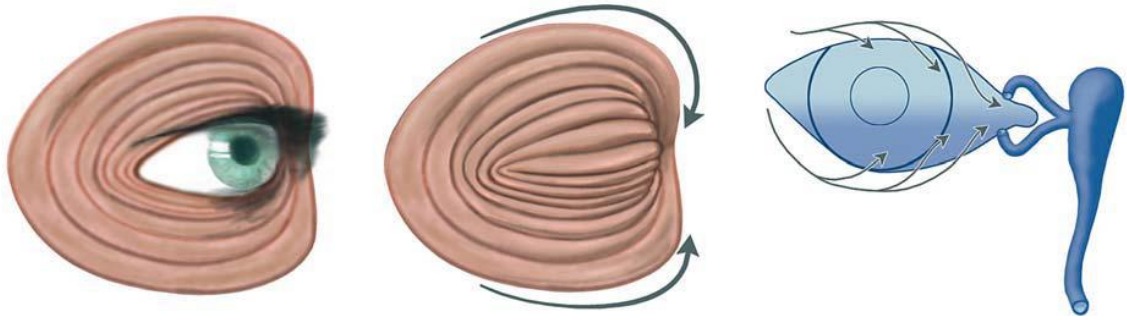
7. Respiration

8. Evaporation

9. Absorption of tear fluid through the lining epithelium of the lacrimal sac and nasolacrimal duct

A decisive role is played by capillary attraction which is aided by contraction of the lacrimal portion of the orbicularis muscle with blinking and with distension of the lacrimal sac by orbicularis muscle. The lamina propria of the lacrimal sac and nasolacrimal duct consist of a thin layer of elastic fibers and many lymphatic cells and a rich venous plexus situated under the loose connective tissue. This venous plexus is connected with the cavernous body of the inferior turbinate. Collagen bundles and elastic and reticular fibers between the blood vessels of the rich venous plexus are arranged in a helical pattern. These fibres are arranged spirally from fornix of lacrimal sac to NLD and contribute biomechanically to tear outflow while blinking. Cavernous body is densely innervated and can increase tear fluid production and can also interrupt it by increasing in size to expel the foreign body. The cavernous body of the efferent tear ducts plays an important role in the physiology of tear outflow regulation.

Under normal conditions tear fluid components are constantly absorbed into the blood vessels of the surrounding cavernous body and then drain to the blood vessels of the outer eye. Cavernous body could act as a feedback signal (autonomic control) for tear fluid production. If these tear components are not absorbed then cavernous body can cease tear fluid production. Rosebgren Doane explained that contraction of orbicularis oculi produce positive pressure in the tear sac to drain tears into nose. When eyelids are fully opened, the puncta pop open and negative pressure draws tears into canaliculi.(21) Disturbance in this mechanism leads to epiphora in facial nerve palsy.



The action of the palpebral part of the orbicularis eye muscle and tear-film dynamics are as shown above. Closure of lid leads to a time shifted contraction of the orbicularis muscle from lateral to medial at the same time moving the tear film to the medial canthal region.(18)

Intranasal surgical anatomy of the lacrimal sac:

Endonasal landmarks are set to establish a correct approach. The landmarks placed on the lateral nasal wall of the nasal cavity: (1)(2)(16)(20) (22) (23) (24)(25)

1. The maxillary line (the protrusion that lies as a curved line from the axilla of the middle turbinate to the inferior turbinate) – **Figure 3 / 4** (25)

2. The axilla of the middle turbinate (the most anterior part of the middle turbinate, where it adheres to the lateral nasal wall) – **Figure 4**

3. The Uncinate process – **Figure 3**

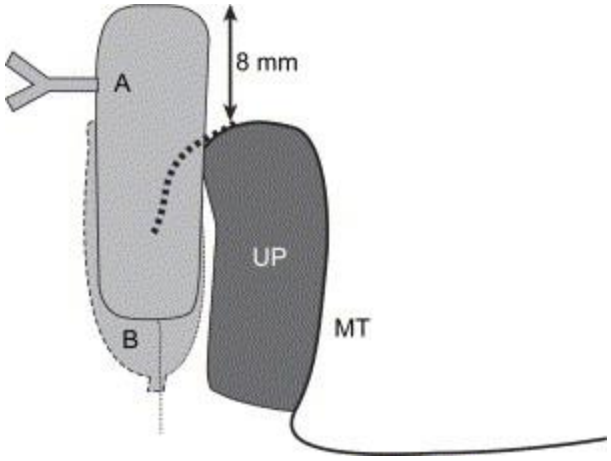
1. **Maxillary line:**

An important landmark for endoscopic dacryocystorhinostomy is the maxillary line. It is a curvilinear eminence which projects from the anterior attachment of the middle turbinate superiorly and extends inferiorly along the lateral nasal wall to end at the root of the inferior turbinate. The line is located near the anterior end of the middle turbinate in the anteroposterior dimension. Extranasally, the maxillary line corresponds to the suture line between the lacrimal bone and the maxilla within the lacrimal fossa and intranasally, the maxillary line marks the attachment of the uncinate process to the maxilla. The midpoint of the maxillary line (**M point**) marks the level of the junction of the lacrimal sac and the nasolacrimal duct anteriorly and the superior aspect of the maxillary sinus ostium posteriorly. M point lies approximately 11 mm posteriorly, incising the uncinate just posterior to maxillary line leads to complete removal of uncinate process.(25)

The axilla of the middle turbinate :

Most early articles and texts (1985-1996) demonstrated that the superior extent of the lacrimal sac was either at or just above the insertion of the middle turbinate on the lateral nasal wall, the so-called axilla of the middle turbinate. (8) (26)(27)(28)

Wormald and colleagues in 2000 evaluated CT scans and CT-Dacryocystograms (CT-DCG) of 47 cases and demonstrated that the sac extends a significant distance (average of 8 mm) above the axilla of the middle turbinate. In addition, they reported that a significant part of the sac was above the entry point of the common canaliculus. They concluded that the sac should be adequately exposed during dacryocystorhinostomy by removal of sufficient bone and mucosa above the anterior insertion of the middle turbinate.(2)



Lacrimal sac position on the lateral nasal wall. The double-ended arrow indicates that the sac extends about 8 mm above the axilla A, lacrimal sac position; B, previously described lacrimal sac position; MT, middle turbinate; UP, uncinate process.(2)

If the bone anterior to the middle turbinate is removed then it leads to expose only the lower half of the sac and marsupialization of the sac is not possible. Therefore, an understanding of the anatomy is vital to a surgeon for the correct placement of mucosal incision and to expose the entire sac.(2)

In a cadaveric study Zhang S-Q et al reported that majority of the lacrimal sac (2/3) was located below the entry point of the common lacrimal canaliculus and about 1/3 lies above it.(23) The common canaliculus provides a valuable landmark. If the common canaliculus can be viewed through the open sac it can be assumed that the dissection and bone removal are sufficiently high. However the sac has to still be opened below to the midpoint of the anterior end of the middle turbinate to prevent sump formation.(2) The placement of the medial canthus is nearly equal to the lacrimal sac placement. This means that, if one tip of nasal bayonet forceps, is placed over the medial canthus, the other tip of the forceps will indicate the lacrimal sac area.(22)

Uncinate process, agger nasi cells: Woo KI et al in 2011 in their CT study reported that the uncinate process was attached to the lacrimal sac fossa in all the 152 cases (100%) at the lower level of the fossa while the agger nasi cell was adjacent to the lacrimal sac fossa in 77.6% cases(29). Woo Ki recommended that uncinate process and agger nasi cell has to be removed for sufficient osteotomy in a significant portion of Asian patients during dacryocystorhinostomy. He also suggested that thick frontal process of the maxilla could be anticipated for the patient with a low nasal bridge.(29)

Lacrimal bone:

Hartikainen J et al in 1996 reported the mean thickness of the lacrimal bone to be 0.106 mm and concluded that lacrimal bone was easily penetrated in most cases. (30) Later Yung et al in their cadaveric study, reported that the thickness of lacrimal bone was 0.057 mm and it covered the posteromedial aspect of the lower lacrimal sac and upper nasolacrimal duct. Lacrimal bone was found to be just anterior to the mid-third of the uncinate process. Yung et al also reported that uncinate process was a reliable landmark of lacrimal bone may and the average length and width of lacrimal bone was 7.4 mm and 2.5 mm, respectively.(31) Ye H et al reported that thickness of lacrimal bone was an average thickness of 0.06 mm.(32)

In Asian patients, the frontal process of the maxilla is very thick compared to other studies. Surgical drills may be required for the Asian patient to expose the upper portion of the sac fossa.(29)

Nasolacrimal duct (NLD)

Caudally the nasolacrimal sac (NLS) directly develops into the nasolacrimal duct (NLD) which lies within the nasolacrimal canal, formed by the lacrimal sulcus of the maxillary bone. Posteromedial aspect upper part of NLD is covered by lacrimal bone and infero-medially it is shaped by the lacrimal process of the inferior nasal turbinate.(20) Ertugrul Tatlisumak et al studied the anatomy of the nasolacrimal duct (NLD) in relation with the lateral nasal wall in 15 half-heads of human adult cadavers. They demonstrated three types of intranasal orifice: pin point, triangular and slit like., NLD was located, on average, 24.6 ± 3.56 mm posterior to the anterior nasal spine. The nearest distance between the NLD and the maxillary sinus ostium was 3.9 ± 0.88 mm. The nearest distances between the opening of the NLD and the nasal floor and between the opening of the NLD and the most anterior attachment of the inferior nasal concha were 13.7 ± 3.15 and 14.3 ± 2.05 mm, respectively. The length of the NLD was an average of 21.9 mm.(24) Ni et al reported that slit-shape orifice of NLD was the most common in all shapes.(33) They also noted the following measurements:

1. The nasolacrimal duct length was an average of14.14 mm.
2. The distance from the inferior margin of the anterior nostril to the anterior margin of the orifice was an average of 29.00 mm
3. The distance from the anterior attachment of the inferior turbinate to the anterior margin of the orifice was 11.70 mm (mean value).
4. The distance from the inferior margin of the anterior nostril to the anterior attachment of the inferior turbinate was 18.30 mm (mean value). (33)

Lacrimal imaging:

The radiologic lacrimal evaluation has evolved during the past 4 decades from x-ray dacryocystograms (DCG) to to CT and MRI evaluation to nuclear medicine isotope examination. Improvement in processor technology leads to efficacy of other imaging like CT scan and provides three-dimensional (3D) views of the nasolacrimal system.(34) A variety of lacrimal imaging studies exist.

Dacryocystography (DCG) allows visualization of anatomic details of the internal lumen of the entire lacrimal drainage system using radio-opaque contrast agent. The patient's head is then imaged using Caldwell's view. A digital subtraction dacryocystography (DS-DCG) is a DCG in which a computer subtracts the surrounding bone and other tissues on the imaging study.(35) On conventional DCG and DS-DCG, the lacrimal sac and duct are smooth, with the sac measuring 4 to 8 mm and the duct measuring 1 to 4 mm in diameter. (36) Lacrimal sac dilatation is assumed if there are greater than 1 to 2 mm size asymmetry on one side. Irregularities in contour with areas of soft tissue density represent inflammatory changes. DCG may reveal normal findings in patients with functional or partial obstructions. The accuracy of DCG is technique-dependent. Dilatation above any stenosis represents that the obstruction is functionally significant. Filling defects may be indicative of neoplasms and dacryoliths. Air bubbles may also be seen, but are typically rounded, sharply demarcated, and change in size and shape. DCG provides help in surgical planning based on site of the obstruction.(35) DCG cannot display information beyond the lumen proper. DCG may show displacement of nasolacrimal apparatus, but peripheral extent of mucosal or disease outside the duct cannot be defined. In these cases, CT may be indicated either initially or as a complementary study.(37)

Computed Tomography(CT):

Specific patients with epiphora and all patients presenting with an inferomedial orbital mass lesion are candidates for CT. Anatomic and pathophysiologic relationships to adjacent tissues are assessed with CT scan and coexistent local nasal or sinus problems can also be diagnosed. High-resolution, thin-section CT imaging (1.0 to 2.5 mm slice thickness) may be an appropriate and useful modality for assessing the nasolacrimal system with its immediate bony confines, the lacrimal fossa, the adjacent orbit, paranasal sinuses (especially the agger nasi cells), and the nasal cavity. Anatomic depiction of the nasolacrimal sac and duct are well viewed in the axial plane. Coronal assessment may also be needed, especially to view the junction of the lacrimal sac and duct and the relationship of the medial orbital floor or nasal cavity structures to the nasolacrimal drainage system. (37) (38)

Russell et al, reported CT anatomy of normal and pathological lacrimal drainage apparatus in 100 patients and readily recognized the bony lacrimal fossa, lacrimal sac and nasolacrimal duct in all cases. They also concluded that sagittal /coronal images reformatted from thin transverse axial sections were often useful in defining the origin of an inferomedial orbital mass and in its relation to the lacrimal sac in case of equivocal clinical studies and axial CT findings . (39) CT or MRI scanning are used in case of suspicion of traumatic, neoplastic, or mechanical secondary acquired nasolacrimal duct obstruction. Combined CT-Dacrocystography (CT- DCG) facilitates visualization of the lacrimal drainage system via three-dimensional reconstruction. Furthermore, it offers the advantage of demonstrating a DCG filling defect while providing CT information on the density of the lesion and surrounding architecture. The sac–duct junction is the most common site of obstruction in the adult patient and CT-DCG shows filling of lumen with

soft tissue density. CT-DCG is considered superior to MRI-DCG for canalicular visualization. The lacrimal sac and duct are equally well visualized with both CT-DCG and MRI-DCG . MRI is probably less useful than CT overall due to its poor imaging of bony erosion or obstruction.(40)

CT Anatomy

Although CT clearly depicts the bony structures related to the lacrimal canal, the sutures between the lacrimal and frontal process of maxilla are too small to allow their exact differentiation. Maxillary sinus is lateral to nasolacrimal canal and middle and inferior nasal meatus are medial to the nasolacrimal canal. The normal lacrimal sac and duct may be either tear-filled (soft-tissue density) or air-filled. An encircling bony canal along the medial aspect of the maxilla depicts the intraosseous component of the duct (**fig. 5**)(41) . The most inferior portion of the nasolacrimal duct, approximately 5 mm in length, represents the membranous (or meatal) portion of the nasolacrimal canal, passing beneath the nasal mucosa before emptying into the inferior meatus through the valve of Hasner which is approximately 1cm posterior to the anterior end of the inferior turbinate.(20) The intraosseous part of the nasolacrimal canal constitutes half of the lower lacrimal drainage system (nasolacrimal duct and sac) but this may vary between 33-67%. The direction of the nasolacrimal sac and duct is dorso-caudal. Groell et al did CT examination in 147 patients and demonstrated that the mean length of the nasolacrimal duct was 11.2 +/- 2.6 mm (range: 6-21 mm), the narrowest diameter was 3.7 +/- 0.7 mm (range: 2-7 mm). The mean length of the nasolacrimal sac was 11.8 +/- 2.5 mm (range: 6-18 mm). The width of the nasolacrimal sac did not exceed 4 mm unless filled with air. (20) Groessl et al demonstrated that women were found to have a smaller bony diameter at the level of the lower fossa and the middle nasolacrimal duct, compared with those of men. The adult

inferior bony fossa increased in size with age in both men and women, while the middle NLD increased in size in men only. They did not find any significant size difference between the right and left side at any level. (42) Men had a mean diameter of 3.9 mm versus women 3.6 mm. Both Caucasian and New Zealand Maori had mean diameters of 3.7 mm whereas Pacific People had mean of 4.1 mm.(43)

Apart from the visualization of the lacrimal drainage system, thin section CT scan provides information regarding the surrounding tissue. This may be particularly important in complex pathologies such as fractures, abscess formation or tumor infiltration and for the planning of surgical interventions.(39) These pathologic processes may mask the structures of the lower lacrimal drainage system and makes differentiation of these structures difficult. (20) Plain or intravenous enhanced CT does not identify the superior and inferior canaliculi or the common canaliculus. The canaliculi may be identified by placement of topical contrast medium into the conjunctival sac.(40)

Relationship in CT scan (Figure 6): (44)

Relationship between the Lacrimal Sac Fossa and the Uncinate Process:

Woo et al in 2011 reported that the anterior insertion of the uncinate process was oblique. It was attached to the lacrimal bone at the lower level, then attached anterior to the maxillary bone- lacrimal bone at the middle level, and finally with the middle turbinate at the upper level.(29). The lacrimal bone is always situated immediately anterior to the mid-third of the uncinate process, an anatomic landmark in endonasal DCR procedures.(31)

Relationship between the Lacrimal Sac Fossa and the Agger Nasi Cell:

The agger nasi cell is the most anteriorly placed anterior ethmoid cell. It has been reported to be present in 78% to 100% of cases. The most anterior ethmoid cell has been described to be removed to perform an osteotomy for dacryocystorhinostomy because it is positioned anteriorly from the posterior lacrimal crest. In some patients, these air cells have been described as possibly extending the entire length of the lacrimal sac fossa, leading to considerable confusion during DCR.(31) In an interracial study using axial CT scans, the ethmoid cell was positioned more anteriorly to the lacrimal sac in Asians compared to whites. So the agger nasi cell needs to be removed more frequently in Asians than in whites based on these findings (29). Analysis showed that agger nasi cells overlie the upper parts of the lacrimal sac in 55% of patients. An anteriorly attaching uncinate process may also cover at least 50% of the lacrimal fossa, was seen in 63% of individuals. So uncinectomy and removal of agger nasi cells would be needed if these structures are found to be anteriorly placed.(45).

Thickness and Proportion of the Frontal Process of the Maxilla in the Lacrimal Sac Fossa:

The thickness and proportion of the maxillary bone in the lacrimal sac fossa increased from the lower to the upper level of the lacrimal sac fossa.(29)

A light source positioned within the lacrimal sac transmits through the tiny lacrimal bone but not the thicker maxillary bone. Such transillumination can assist to remove the bone at the posteromedial portion of the inferior lacrimal sac–superior nasolacrimal duct area.(31) Mccormick A et al in their study, reported that sinusitis was the commonest

finding in 36%. Seventeen per cent had no abnormality reported. The other findings were: nasal polyps; frontal lobe abscess; hard palate cyst; dacryoadenitis; septal deviation; middle ear disease.(43) Francis et al reported that preoperative CT led to an alteration of patient management. Conditions such as tumor, ethmoiditis, soft tissue opacity in the nasolacrimal duct, gross nasal polyposis, fungal sinusitis, and a dacryolith were observed by CT.(37) Similar to the role in functional endoscopic sinus surgery, CT imaging also have important role in the assessment of many patients with symptoms of lacrimal drainage obstruction.(37)

The success rate of external DCR in the literature has often been reported to be better than that of the endonasal approach (89–95 per cent vs. 75–90 per cent, respectively). However endoscopic dacryocystorhinostomy, compared with external D.C.R. has the following advantages: greater cosmetic acceptability, minimal blood loss, no injury to physiological lacrimal pump mechanism and simultaneous management of intranasal pathology.(46) Removal of the medial wall of the lacrimal sac had high success rates compared to the simple incision and drainage approach.(47) Studies have suggested that factors promoting lacrimal sac scarring may decrease the success rate of endonasal DCR including previous nasal surgery or DCR and multisystem disease such as sarcoidosis or Wegener granulomatosis. A narrow intranasal view and bleeding appear to increase the difficulty for the surgeon .A small lacrimal sac opening was associated with failure of endonasal DCR. (48)

Cause of failure of ENDO-DCR and role of surgical anatomy:

Welham and Wulc reviewed 208 failed DCRs and found that the major reasons for failure were errors in the bony ostium size and location. They also found that incomplete

opening tended to result in sump formation in the inferior dependent part of the mucocele, with consequent infections of inspissated secretions, resulting in recurrent epiphora even in the presence of a patent ostium.(49) Mannor and Millman showed in their study that patients with preoperative mucoceles in whom a large ostium could be created had a significantly suggested that the sac be opened as widely as possible during surgery to achieve the highest possible success rate in intranasal endoscopic DCR. (50) With the external technique, bone removal deep to the sac is extensive, and the entire sac wall is anastomosed to the nasal mucosa. One of the main reasons for failure of the external DCR technique is inadequate bone removal, specifically above the insertion of the middle turbinate. This could also be a contributory factor in endoscopic DCR as the bone above the insertion of the middle turbinate is thick and difficult to remove.(2) Literature suggests that the success rate of the DCR does correlate to the size of the original ostium. Hehar et al created a small ostium of around 0.4 to 0.5 mm and achieved a success rate of only 70%.(51) This is in contrast to the larger ostium sizes created by Weidenbacher et al(52) and Sprekelsen and Barberán(28) with reported success rates of 85% to 90%, respectively. Underexposure or lack of true localization of the sac are the most frequently encountered reasons for dacryocystorhinostomy failure. The maxillary line and axilla are the 2 most important landmarks in localization of the sac. A mucosal incision anterior to the maxillary line followed by osteotomy on the lacrimomaxillary suture and above the axilla nearly always ensure the exposure of the sac. (1) Research into the intranasal anatomy of the lacrimal sac has shown that the rhinostomy needs to be larger and higher on the lateral wall, from the frontal process of the maxilla, the lacrimal bone, as well as the bone above the axilla. This rhinostomy includes the agger nasi cell and extends posteriorly to the insertion of the uncinate. This osteotomy leads to expose the whole lacrimal sac(53) Fayet B et al recommended that anterior resection of the uncinate

process is the most important surgical step to expose the medial aspect of the lacrimal fossa during endonasal DCR.(54)

Despite favourable results compared with conventional surgical treatment, complications and surgical failure can still easily occur because the endoscope only allows monocular and limited vision and limited scope of the operative field. The success and safety of intranasal endoscopic surgery primarily depend on the surgeon's knowledge of intranasal anatomy , especially of nasolacrimal system and it's relation to lateral nasal wall. Cadaver studies are still a valuable approach by which surgeons can increase their knowledge and understanding of the anatomy of the area (24)

MATERIALS AND METHODS

a) Study design:

This was a descriptive study (Cadaver dissection/case series) in which data collection was done by measurement of anatomical landmarks in CT scan and cadaver sagittal head sections.

b) Participants: Ten adult cadaver's head sections (10 right and 10 left sagittally sectioned specimens) fixed with 10% formaldehyde solution (**fig-7**).

c) Setting: Anatomy and Radiodiagnosis department of a tertiary hospital.

e) Methods:

Ten adult cadaver's head sections, fixed with 10 % formaldehyde solution were identified. Plain CT-PNS (paranasal sinuses , 0.8 mm axial sections with 0.4mm overlap, were done from vertex to mandible,**fig-8**.) Coronal and sagittal sections were reconstructed from these axial sections. Measurements were made on the CT images using electronic calipers on PACS (picture archival and communication system). These cadavers head were then sagittally sectioned. This was followed by dissection of nasolacrimal system on each sagittal head section. Digital calliper (**fig-9**) was used to measure distances on dissection.

During the dissection, the maxillary line was determined by the retraction of the middle turbinate superiorly (**fig-10 A**). After the retraction, an incision that involved both the mucosa and periosteum were made through this line. The mucosa and periosteum were

elevated, and the lacrimomaxillary suture was exposed. In this way, the relation between the lacrimomaxillary suture and maxillary line was noted. As a next step, the nasolacrimal duct and lacrimal sac were dissected by the removal of the lacrimal bone (posterior to the lacrimomaxillary suture) and the frontal process of maxilla (anterior to the lacrimomaxillary suture: **fig-10 B)**. The relation of the lacrimal bone to the lacrimal sac was also noted. In cadavers heads agger nasi were noted and had to be excised to expose nasolacrimal sac. The maxillary sinus ostium was then revealed by removing the uncinate process. Part of inferior turbinate was excised to expose nasolacrimal duct. This completed the exposure of nasolacrimal system (**fig-10 C)**.

The features/ dimensions noted on cadaveric dissection and feasible dimensions noted on CT scan were tabulated as below mentioned.

MEASUREMENTS (ON DISSECTION)	**CT SCAN**
Maxillary line:_____clear, not clear	NOT APPLICABLE AS SOFT TISSUE LANDMARK(NA)
Length of maxillary line- from axilla to inferior turbinate	NA
Distance from Anterior nasal spine to genu (anterior most and lower most free part of the middle turbinate as noted endoscopically)	Measurement was made on midline sagittal sections. The most anterior point was identified on axial and coronal sections and the 'cross reference' tool in PACS was used to show the spot on the sagittal images. The medio-lateral component of this measurement is not taken into account on the CT measurement.
Anterior nasal spine to axilla of middle turbinate	Similar to above
Anterior nasal spine to M point (mid point of maxillary line)\	NA

MEASUREMENTS (ON DISSECTION)	CT SCAN
Maxillary sinus ostium to M point	NA
Relation of lacrimomaxillary suture line to maxillary line(anterior/posterior/over)	NA
Thickness of lacrimal bone	Smallest measurement possible was 0.4mm
After removal of lacrimal bone: lacrimal sac seen (more than half _____/less than half / not seen___)	NA
Distance between Posterior edge of lacrimal sac(the most posterior part of bulge of lacrimal sac) and axilla of middle turbinate	Craniocaudal distance was measured on coronal images by identifying the maximum bulge of lacrimal sac and axilla of middle turbinate on axial sections and using the cross reference tool to mark them on the coronal images. AP and medio-lateral components of this distance are not included in the CT measurement.
Anterior edge of lacrimal sac (the most anterior part of bulge of lacrimal sac) and axilla of middle turbinate	Same as above
Posterior edge of lacrimal sac to anterior most point of middle turbinate	Craniocaudal distance measured using similar method as above.
Posterior edge of lacrimal sac and maxillary sinus ostium	Craniocaudal dimension
Posterior edge of lacrimal sac and ethmoidal bullae (Nearest distance)	NA
Superior end of sac (at / below/ above axilla)	By identifying the superior end of the sac and the axilla of middle turbinate on axial and coronal images, their relationship was assessed.
inferior edge of lacrimal sac and inferior turbinate	NA
Anteroposterior diameter of lacrimal sac	Maximum diameter measured on the axial sections. If the sac was air filled,

MEASUREMENTS (ON DISSECTION)	CT SCAN
	maximum AP diameter of the air filled sac was measured. If not, the bony fossa was measured.
. Length of lacrimal sac	Craniocaudal dimension measured on coronal images after identifying the fundus and transition point between the lacrimal sac and duct on axial images and using the cross reference tool on PACS.
. Distance between:	
Fornix(superior end) of lacrimal sac and axilla of middle turbinate	Craniocaudal dimension measured on coronal images, similar to the previous measurement
Fornix to ostium	Craniocaudal dimension measured on coronal images
Anterior nasal spine and fornix of lacrimal sac	Craniocaudal dimension measured on coronal images
Anterior nasal spine and inferior edge of lacrimal sac	NA
. The relationship between the lacrimal sac and the axilla of the middle nasal concha.	Assessed on axial images
. The relation between the lacrimal sac and the maxillary line.	NA
. Nearest distance between Posterior edge of nasolacrimal duct and ethmoidal bullae	Assessed on axial images
. Relation of anterior point of middle turbinate to nasolacrimal duct:(at/anterior/posterior)	NA
. Nearest distance between genu (…) to duct	Assessed on axial images

MEASUREMENTS (ON DISSECTION)	CT SCAN
. Length of the nasolacrimal duct (from the transition area between the sac and duct up to the intranasal orifice)	Craniocaudal dimension measured on coronal images.
. Nearest distance from the a) Nasolacrimal duct to the maxillary sinus ostium	Assessed on axial images
b) The Nasolacrimal duct to the anterior nasal spine	Antero-posterior dimension was assessed on sagittal images of the NLD, by using the cross reference tool to identify the level the anterior nasal spine. The mediolateral and cranio-caudal components of this dimension were not included in the CT measurement.
c) Intranasal orifice of the nasolacrimal duct to the nasal floor	Assessed on coronal images
l) Intranasal orifice of the nasolacrimal duct to anterior attachment of the inferior turbinate.	Anteroposterior measurement was assessed on axial images

h) Statistical Analysis:

SPSS ver. 16.0 was used for statistics. Mean, standard deviation and the minimum and maximum values of all measurements were determined, and the values were rounded into values having two digits after the points. Correlation analysis between cadaveric dissection and CT scan was done by scatter plot and Pearson Correlation. A paired t test was applied to determine whether a significant statistical difference existed in the measurements between the right and left side.

RESULTS AND ANALYSIS

Ten adult cadaver's head sections (10 right and 10 left, n=20) fixed with 10% formaldehyde solution were evaluated.

Table 1: Maxillary line – Clear/ Not clear

Maxillary line	Clear	Not clear
Right(n=10)	8	2
Left(n=10)	7	3
Total(n=20)	15(75%)	5(25%)

Maxillary line was clear in 15(75%) cases and not clear in 5(25%) cases.

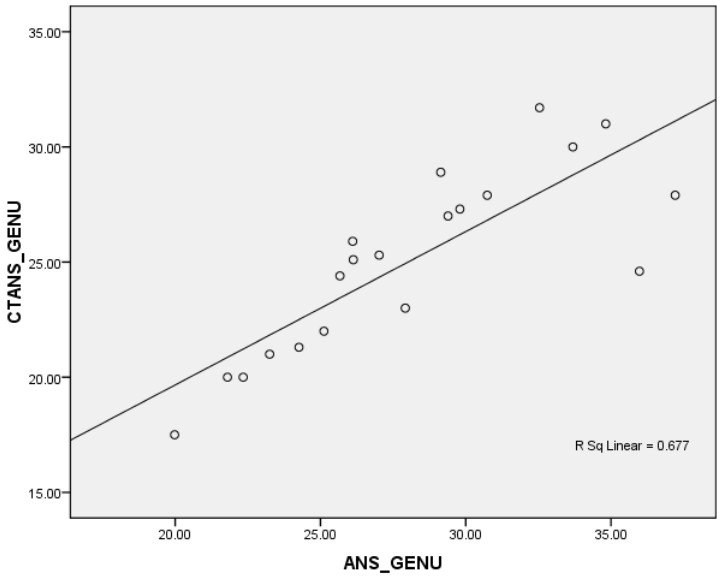
Table 2: Length of maxillary line- from axilla to inferior turbinate (in mm); Fig 11

	Length-Mean(SD)	Range	P –value
Right(n=10)	12.69 (2.33)	9.59-15.82	0.580
Left(n=10)	12.38(2.76)	8.09-16.79	
Total(n=20)	12.54(2.49)	8.09-16.79	

The mean (SD) length of maxillary line was measured as 12.54 (2.49) mm (range, 8.09-16.79 mm).In our study we also noted that M point marks the level of superior aspect of the maxillary sinus ostium posteriorly, and the junction of the lacrimal sac and the nasolacrimal duct anteriorly in all cadavers.

Table 3. Distance from anterior nasal spine to genu of middle turbinate (in mm); fig. 12

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-**	**Mean (SD)**	**Range**	**p-**
Right(n=10)	27.99(4.97)	21.8-35.98		25.27(4.15)	20-31.70	
Left(n=10)	28.29(5.08)	19.98-	0.806	24.91(3.97)	17.5-31.0	0.797
Total(n=20)	28.15(4.89)	19.98-		25.09(3.95)	17.50-	



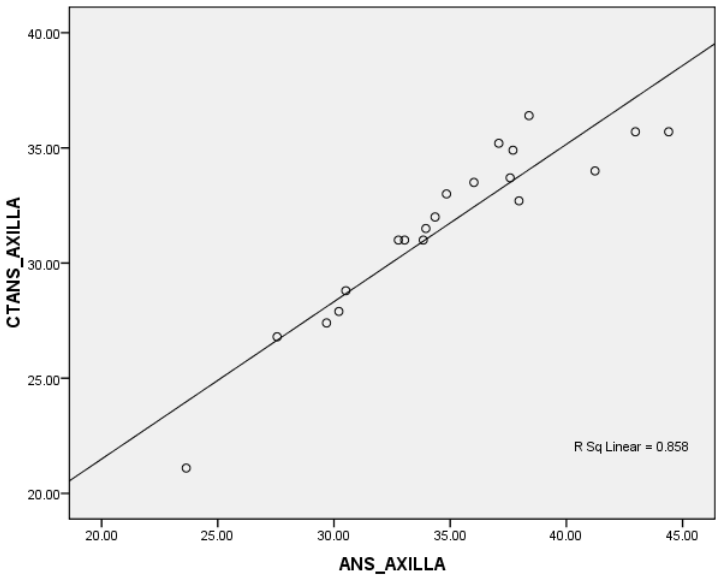
	Correlation coefficient	**R square**	**P-value**
ANS-GENU *	**0.823**	**0.677**	**.000(<0.01)**
CT ANS-GENU			

(* Distance from anterior nasal spine to genu of middle turbinate)

Strong positive correlation between above mentioned two variable of 0.823 was noted, which was found to be statistically significant (p<0.01.)

Table 4: Anterior nasal spine to axilla of middle turbinate (in mm); fig. 13

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	34.86(5.31)	27.55-44.40	0.962	31.46(3.09)	26.8-35.70	0.736
Left(n=10)	34.91(5.21)	23.64-42.97		31.87(4.53)	21.10-36.40	
Total(n=20)	34.89(5.11)	23.64-44.40		31.67(3.77)	21.10- 36.40	



	Correlation coefficient (Pearson correlation)	R sq linear	P-value
ANS-AXILLA	.926	0.858	**.000(<0.01)**
CT ANS-AXILLA			

(* Anterior nasal spine to axilla of middle turbinate)

Strong positive correlation between above mentioned two variable of 0.926 was noted, which was found to be statistically significant (p<0.01.)

Table 5: Anterior nasal spine to M point (mid point of maxillary line)-in mm

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	29.79(5.68)	23.58-39.42	0.878
Left(n=10)	30.07(4.77)	20.25-38.19	
Total(n=20)	29.93(5.10)	20.25-39.42	

Table 6: Maxillary sinus ostium to M point (in mm)

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	8.74(1.44)	6.24-11.00	0.456
Left(n=10)	9.13(2.22)	6.45-12.41	
Total(n=20)	8.93(1.83)	6.24-12.41	

Table 7: Relation of lacrimomaxillary suture line to maxillary line

	Relation (anterior/posterior/over)		
Side	**Relation-anterior**	**Posterior**	**Over**
Right(n=10)	1	4	5
Left(n=10)	2	5	3
Total(n=20)	3	9	8

Lacrimomaxillary suture was seen posterior to maxillary line in 9(45%) and over maxillary line in 8(40%) specimens.

Table 8: Thickness of lacrimal bone(in mm)

Side	Thickness (dissection) Mean (SD)	Range	p-value
Right(n=10)	0.25(0.070)	0.14-0.35	0.842
Left(n=10)	0.25(.053)	0.15-0.33	
Total(n=20)	0.25(.061)	0.14-0.35	

CT measurements could not be done as smallest measurement possible was of 0.4mm.

Table 9: After removal of lacrimal bone: lacrimal sac seen (less than half_____/ not seen)

Side	Side	Less than half	Not seen
Right(n=10)	**Right**	9	1
Left(n=10)	**Left**	10	0
Total(n=20)	**Total**	19(95%)	1(5%)

After removal of lacrimal bone, a lower part of lacrimal sac was seen in 19(95%) of cases.

Table 10: Distance between posterior edge of lacrimal sac and axilla (mm)

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	8.59(1.27)	6.29-10.83	0.500	8.37(1.7)	5.9-11.6	0.635
Left(n=10)	8.94(1.85)	6.02-12		8.67(1.66)	5.7-11.3	
Total(n=20)	8.76(1.55)	6.02-12		8.52(1.64)	5.7-11.6	

	Correlation coefficient (Pearson correlation)	R sq linear	P-value
LS post-_Ax *	.163	0.027	0.492
CT LSpost-_Ax			

(* Distance between posterior edge of lacrimal sac and axilla)

There was no evidence to prove any correlation between two variable , which was found to be statistically insignificant (p=0.492)

Table 11: Distance between anterior edge of lacrimal sac and axilla (mm)

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	10.84(1.88)	6.33-13.44	0.255	10.02(1.95)	7.0-12.4	0.693
Left(n=10)	10.31(1.13)	7.65-12		9.76(1.48)	7.9-12.3	
Total(n=20)	10.58(1.54)	6.33-13.44		9.89(1.69)	7.0-12.4	

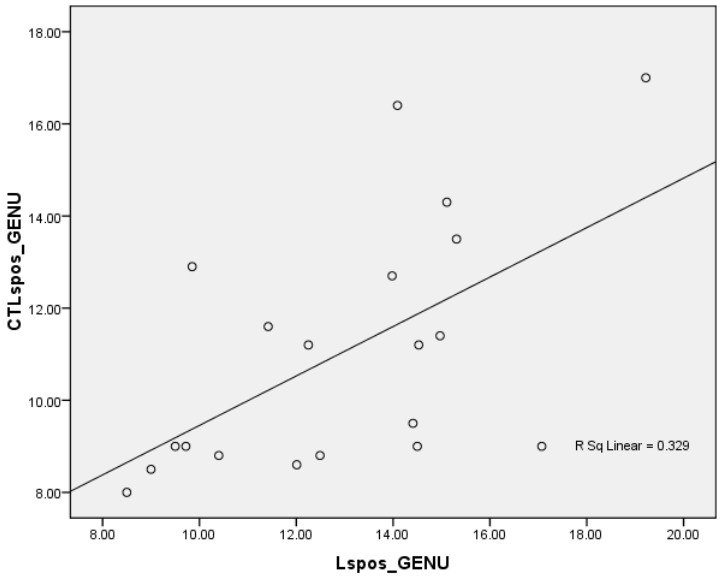
	Correlation coefficient	R sq linear	P-value
LS ant_Ax	**0.222**	**0.049**	0.346
CT LS ant_Ax			

(* Distance between anterior edge of lacrimal sac and axilla)

There was no evidence to prove any correlation between above mentioned two variable, which was found to be statistically insignificant (p=0.346**)**

Table 12: Posterior edge of lacrimal sac to genu of middle turbinate (in mm)

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	12.56(2.80)	9-17.07	0.446	10.55(2.23)	8.5-14.3	0.387
Left(n=10)	13.27(3.06)	8.5-19.22		11.49(3.14)	8-17	
Total(n=20)	12.91(2.88)	8.50-19.22		11.02(2.69)	8.0-17.0	



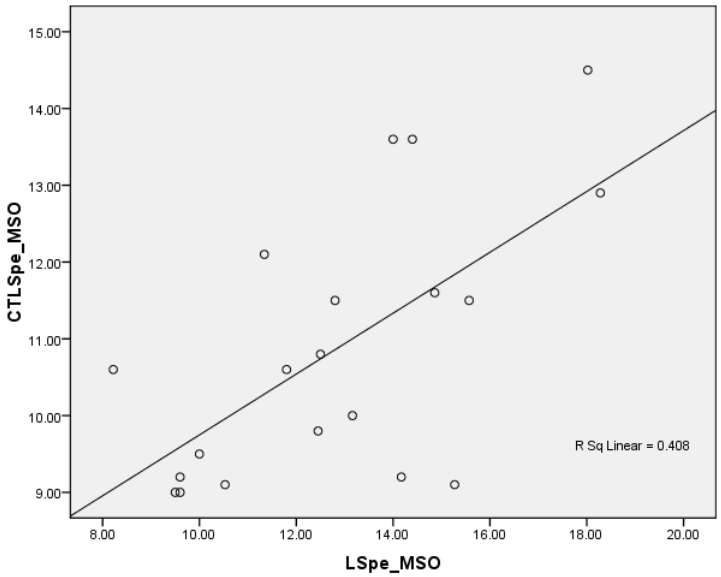
	Correlation coefficient	**R square**	**P-value**
Lspos_GENU	**0.573**	**0.329**	0.008
CT Lspos_GENU			

(* Posterior edge of lacrimal sac to genu of middle turbinate)

Positive correlation between above mentioned two variable of 0.573 was noted, which was found to be statistically significant (p=0.008.)

Table 13: Posterior edge of lacrimal sac and maxillary sinus ostium (in mm)

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	12.35(3.00)	8.22-18.02	0.340	11(1.94)	9.0-14.5	0.443
Left(n=10)	13.25(2.69)	9.6-18.28		10.72(1.62)	9.0-13.6	
Total(n=20)	12.80(2.80)	8.22-18.28		10.86(1.74)	9.0-14.5	



	Correlation coefficient	**R square**	**P-value**
LS pe_MSO * CT LSpe_MSO	**0.638**	**0.408**	0.002

(* Posterior edge of lacrimal sac and maxillary sinus ostium)

Positive correlation between above mentioned two variable of 0.638 was noted, which was found to be statistically significant (p=0.008.)

Table 14: Posterior edge of lacrimal sac and ethmoidal bullae(in mm)

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	9.10(2.16)	6.08-13	0.505
Left(n=10)	8.54(2.19)	5.51-12.57	
Total(n=20)	8.82(2.14)	5.51-13	

Table 15: Superior end of sac (at / below/ above axilla)

Side	Above axilla	Below axilla
Right(n=10)	10	0
Left(n=10)	10	0
Total(n=20)	20(100%)	0

In all cases superior end of sac was above axilla.

Table 16: Distance between inferior edge of lacrimal sac and inferior turbinate(in mm)

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	7.73(0.70)	6.68-8.92	0.4
Left(n=10)	8.08(1.20)	6.37-10.47	
Total(n=20)	7.90(0.97)	6.37-10.47	

Table 17: Anteroposterior diameter of lacrimal sac (in mm):

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	7.53(1.53)	5.84-10.58	0.406	6.81(1.56)	5.00-9.80	0.517
Left(n=10)	7.177(1.48)	5.54-10.07		6.49(1.08)	5.10-8.40	
Total(n=20)	7.354(1.47)	5.54-10.58		6.65(1.32)	5.00-9.80	

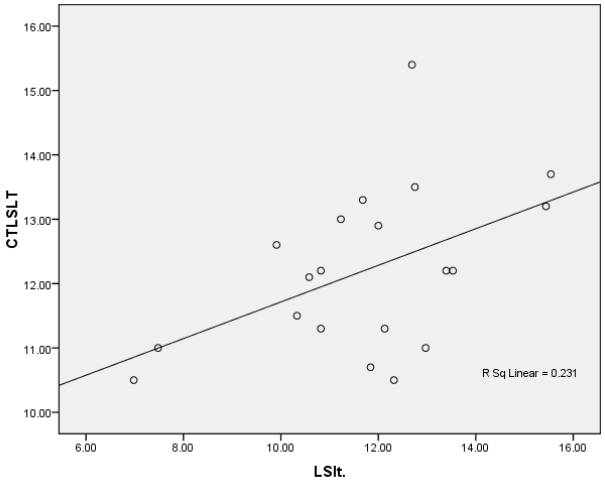
	Correlation coefficient	**R square**	**P-value**
LSap *	0.257	0.066	0.274
CT LSap			

(*Anteroposterior diameter of lacrimal sac)

There was no evidence to prove any correlation between above mentioned two variable, which was found to be statistically insignificant (p=0.274**)**

Table 18: Length of lacrimal sac (in mm); Fig.14

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	11.27(1.62)	7.48-13.53	0.123	12.22(0.97)	10.7-13.5	0.933
Left(n=10)	12.17(2.58)	6.98-15.54		12.19(1.57)	10.5-15.4	
Total(n=20)	11.72(2.145)	6.98-15.54		12.21(1.27)	10.5-15.4	



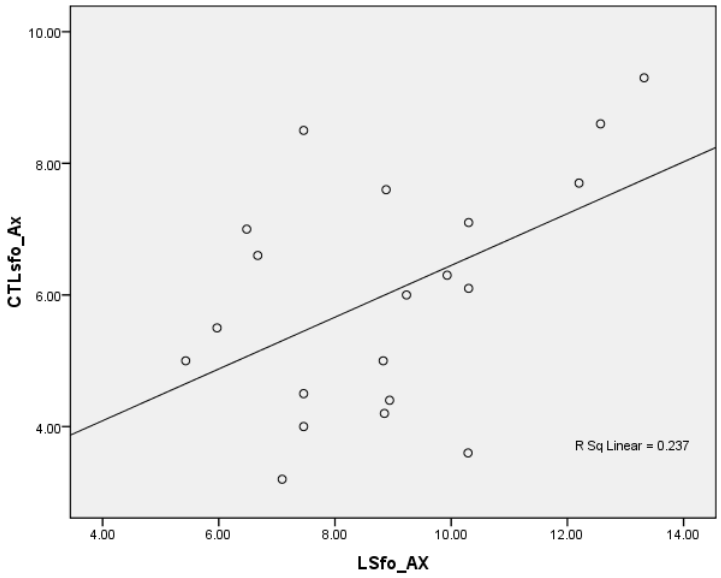
	Correlation coefficient	R square	P-value
LSlt *	0.480	0.231	0.032
CT LSlt			

(* Length of lacrimal sac)

Positive correlation between above mentioned two variable of 0.480 was noted, which was found to be statistically significant (p=0.032.)

Table 19: Distance between Fornix (superior end) of lacrimal sac and axilla of middle turbinate (in mm): fig-15

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	8.48(2.17)	5.43-12.20	0.394	5.79(1.44)	3.20-7.70	0.431
Left(n=10)	9.29(2.27)	5.97-13.32		6.23(2.11)	3.60-9.30	
Total(n=20)	8.88(2.2)	5.43-13.32		6.01(1.78)	3.2-9.3	



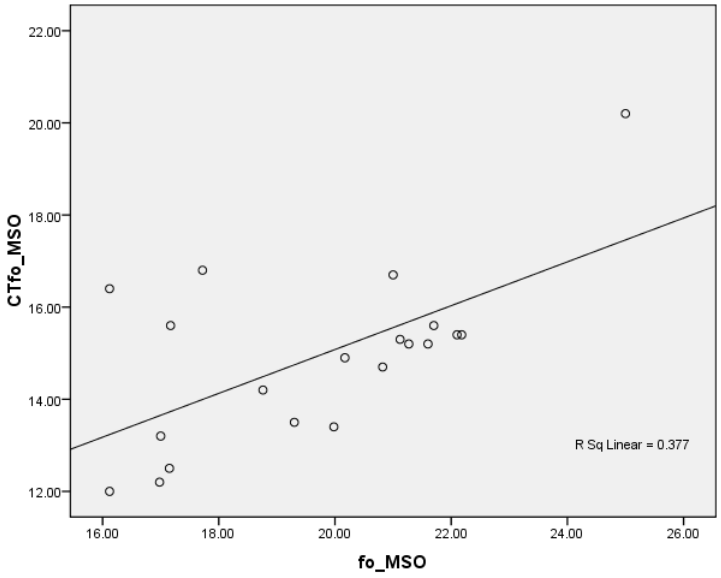
	Correlation coefficient	R square	P-value
LSfo-_AX *	0.487	0.237	0.029
CT LSfo-AX			

(* Distance between Fornix (superior end) of lacrimal sac and axilla of middle turbinate)

Positive correlation between above mentioned two variable of 0.487 was noted, which was found to be statistically significant (p=0.029)

Table 20: Fornix to ostium (in mm); fig. 16

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	19.03(2.17)	16.12-21.7	0.253	14.83(1.62)	12.00-16.8	0.776
Left(n=10)	20.29(2.65)	16.98-25.0		15.01(2.21)	12.2-20.20	
Total(n=20)	19.66(2.44)	16.12-25.0		14.92(1.9)	12.00-20.20	



	Correlation coefficient	R square	P-value
fo_MSO *	0.614	0.377	0.004
CT fo_MSO			

(* Fornix to ostium)

Positive correlation between above mentioned two variable of 0.614 was noted, which was found to be statistically significant (p=0.004)

Table 21: Anterior nasal spine and fornix of lacrimal sac (in mm)

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	41.22(4.97)	32.97-48.63	0.357	37.07(5.83)	22.6-43	0.190
Left(n=10)	39.86(4.77)	30.46-48.75		35.88	18.5-44.3	
Total(n=20)	40.54(4.8)	30.46-48.7		36.47(6.19)	18.50-44.30	

	Correlation coefficient	**R square**	**P-value**
ANS_LSfo *	0.136	0.018	0.569
CT ANS_LSfo			

(* Anterior nasal spine and fornix of lacrimal sac)

There was no evidence to prove any correlation between above mentioned two variable, which was found to be statistically insignificant (p=0.569**)**

Table 22: Anterior nasal spine and inferior edge of lacrimal sac(in mm)

Side	**Distance Mean (SD)**	**Range**	**P –value**
Right(n=10)	32.41(4.85)	23.41-39.65	0.807
Left(n=10)	32.1(4.38)	24.63-40.02	
Total(n=20)	32.26(4.5)	23.41-40.02	

There was no evidence to prove any correlation between above mentioned two variable, which was found to be statistically insignificant (p=0.274**)**

Table 23: The relationship between the lacrimal sac and the axilla of the middle nasal concha

Side	Dissection		CT scan	
	More than	Less than	More than	Less than
Right	6	4	6	4
Left	6	4	6	4
Total	12(60%)	8(40%)	12(60%)	8(40%)

Lacrimal sac was more than half above the axilla in 60% of cases and was less than half above the axilla in 40 % of cases.

Table 24: The relation between the lacrimal sac and the maxillary line

Side	Relation		
	Less than	More than	Full anterior
Right	3	7	0
Left	4	5	1
Total	7(35%)	12(60%)	1(5%)

Lacrimal sac was more than half anterior to maxillary line in 60 % of cases and less than half anterior in 35% of cases and in one case lacrimal sac was found fully anteriorly.

Table 25: Nearest distance between Posterior edge of nasolacrimal duct and ethmoidal bullae (in mm)

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	9.22(2.97)	5.15-13.16	0.876
Left(n=10)	9.09(2.41)	6.53-13.25	
Total(n=20)	9.152(2.63)	5.15-13.25	

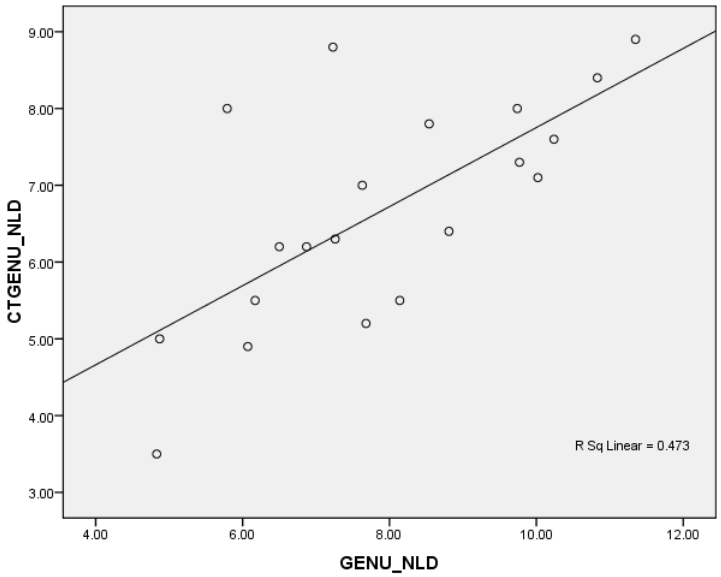
Table 26: Relation of anterior point of middle turbinate to nasolacrimal duct: (at/anterior/posterior)

Side	Relation					
	Anterior	**Anterior**	**At**	**At**	**Posterior**	**posterior**
Right	0	0	5	5	5	5
Left	1	1	4	4	5	5
Total	1(5%)	1(5%)	9(45%)	9(45%)	10(50%)	10(50%)

Middle turbinate genu was at NLD in 45% of cases and posterior in 50% of cases and anterior in 5% of cases.

Table 27: Nearest distance between genu to duct (in mm); fig.17

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	7.64(2.21)	4.83-11.35	0.37	6.34(1.69)	3.50-8.9	0.11
Left(n=10)	8.19(1.71)	6.07-10.83		7.02(1.78)	4.90-8.80	
Total(n=20)	7.92(1.95)			6.68(1.46)		



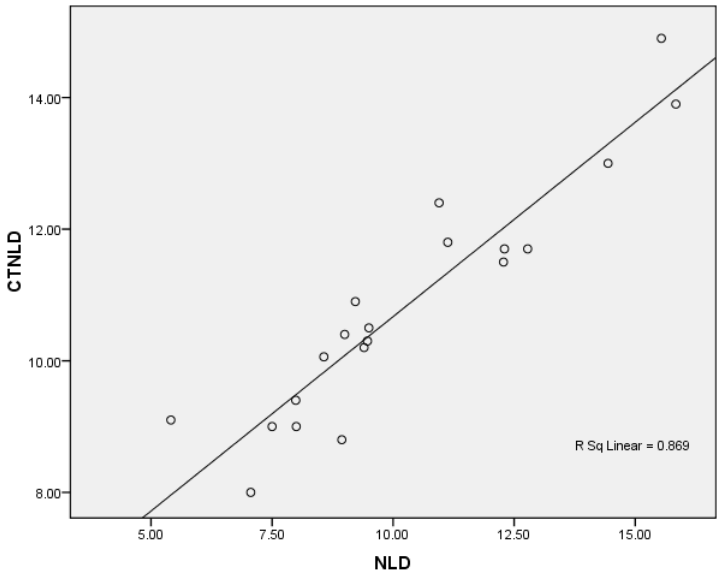
	Correlation coefficient	R square	P-value
GENU_NLD *	0.688	0.473	0.001
CT GENU_NLD			

(* Nearest distance between genu to duct)

Positive correlation between above mentioned two variable of 0.688 was noted, which was found to be statistically significant (p=0.001)

Table 28: Length of the nasolacrimal duct (from the transition area between the sac and duct up to the intranasal orifice)-in mm: fig.18

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	9.99(3.19)	5.41-15.54	0.363	10.66(2.09)	8.0-14.9	0.475
Left(n=10)	10.55(2.58)	7.50-15.84		11(1.56)	9-13.9	
Total(n=20)	10.27(2.84)	5.41-15.84		10.83(1.8)	8.0-14.9	



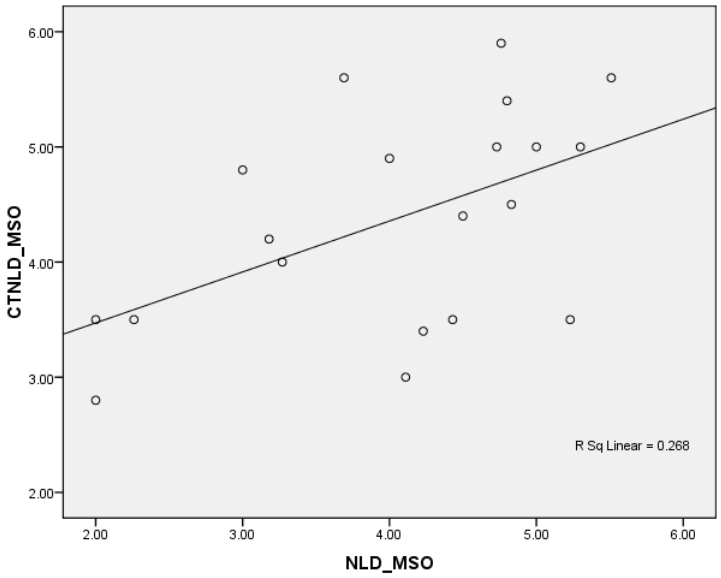
	Correlation coefficient	R square	P-value
NLD *	0.932	0.869	0.000
CT NLD			

(* Length of the nasolacrimal duct)

Positive correlation between above mentioned two variable of 0.932 was noted, which was found to be statistically significant (p=0.000,p=< .01)

Table 29: Nearest distance from the Nasolacrimal duct to the maxillary sinus ostium (in mm); fig. 19

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	3.97(1.16)	2.0-5.51	0.734	4.3(0.87)	3.4-5.60	0.594
Left(n=10)	4.11(1.08)	2.0-5.3		4.45(1.03)	2.8-5.9	
Total(n=20)	4.042(1.09)	2-5.51		4.38(0.93)	2.8-5.9	



	Correlation coefficient	R square	P-value
NLD_MSO * CT NLD_MSO	0.518	0.268	0.019

(* Nearest distance from the Nasolacrimal duct to the maxillary sinus ostium)

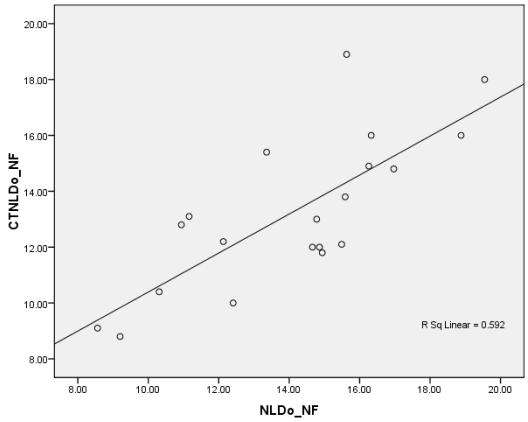
Positive correlation between above mentioned two variable of 0.518 was noted, which was found to be statistically significant (p=.019)

Table 30 : The Nasolacrimal duct to the anterior nasal spine(in mm)

Side	Distance Mean (SD)	Range	P –value
Right(n=10)	25.13(5.31)	16.13-33.04	0.844
Left(n=10)	25.42(3.67)	20.17-32.60	
Total(n=20)	25.27(4.45)	16.13-33.04	

Table 31 : Intranasal orifice of the nasolacrimal duct to the nasal floor (in mm):

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	13.86(2.9)	8.56-16.97	0.508	12.89(3.04)	8.8-18.9	0.396
Left(n=10)	14.34(3.27)	10.31-19.55		13.62(2.53)	10.0-18.0	
Total(n=20)	14.11(3.02)	8.56-19.55		13.255(2.75)	8.80-18.9	



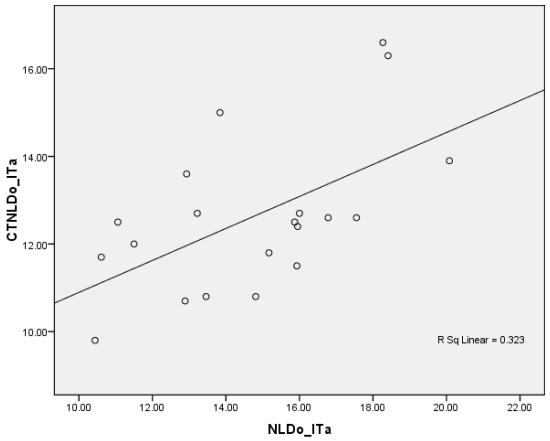
	Correlation coefficient	R square	P-value
NLDo_NF *	0.769	0.592	0.000
CT NLDo_NF			

(* Intranasal orifice of the nasolacrimal duct to the nasal floor)

Strong positive correlation between above mentioned two variable of 0.769 was noted, which was found to be statistically significant (p=.000)

Table 32: Intranasal orifice of the nasolacrimal duct to anterior attachment of the inferior turbinate (in mm): fig 20

	Dissection			CT Scan		
	Mean (SD)	**Range**	**p-value**	**Mean (SD)**	**Range**	**p-value**
Right(n=10)	14.46(2.63)	10.44-18.41	0.499	12.85(1.81)	9.8-16.3	0.420
Left(n=10)	15.02(2.98)	10.61-20.08		12.4(1.78)	10.70-12.4	
Total(n=20)	14.74(2.75)	10.44-20.08		12.63(1.76)	9.80-16.6	



	Correlation coefficient	R square	P-value
NLDo_ITa *	0.569	0.323	0.009
CT NLDo_ITa			

(* Intranasal orifice of the nasolacrimal duct to genu)

Positive correlation between above mentioned two variable of 0.569 was noted, which was found to be statistically significant (p=.009)

The application of a **paired t test** was done to detect whether a statistically significant difference existed in all the measurements between the right and left parts of the specimen, which revealed no such difference.

Discussion

Endonasal endoscopic dacryocystorhinostomy (ENDO-DCR) for surgical treatment for epiphora has become preferred alternative to external dacrocystorhinostomy. (27)(55) It is also well established that a thorough knowledge of the detailed anatomy of nasolacrimal duct (NLD) and nasolacrimal sac (NLS) are essential for a successful surgical outcome of this procedure.(2) Various landmarks have been described to identify nasolacrimal duct and nasolacrimal sac for ENDO-DCR. Taking into consideration the existing landmarks, this study was done to review the anatomy of nasolacrimal system and to correlate these dissection findings with CT scan measurements as a prelude to ENDO-DCR.

In ENDO-DCR the initial landmarks reported are maxillary line and M point. (56) (25).The maxillary line as mentioned earlier is a curvilinear, mucosal eminence from axilla to dorsum of inferior turbinate. (56) (25) Maxillary line was clearly identified in 15 (75%) and not clear in five (25%) cadavers in our study (table no. 1). This is similar to findings of study done by Chastain et al, who reported that the maxillary line could be identified in 88% of their cadaveric study. In our study, the mean length of maxillary line was found to be an average of 12.54 mm (table 2). This has not been reported earlier. We have noted that in the cadavers, where maxillary line was not clear, a ridge was always present on the superior surface of inferior turbinate, near it's medial border (**fig. 11 & 21**). An imaginary line can be drawn from anterior end of this ridge to the axilla which could represent the maxillary line and assist the surgeon to initiate the ENDO-DCR. This has not been previously reported. In the axial plane, the midpoint of the maxillary line (M point) marks the level of the superior aspect of the maxillary sinus ostium posteriorly, and the junction of the lacrimal sac and the nasolacrimal duct anteriorly. (25) In our study too, we noted that M point marks the level of superior aspect of the maxillary sinus

ostium posteriorly, and the junction of the lacrimal sac and the nasolacrimal duct anteriorly in all cadavers.

In our study the distance between the anterior nasal spine and genu (anterior most and lower most free part of the middle turbinate as noted endoscopically) was noted to be an average of 28.15 mm (19.98-37.21) by dissection and this showed a positive correlation with CT measurement (table 3). The distance between the anterior nasal spine and axilla (anterior most attachment of the MT to the lateral nasal wall) was noted as an average of 34.89 mm (23.64-44.40) by dissection and also showed positive correlation with CT measurement (table 4). As an endoscopic surgeon considering ENDO–DCR, these two measurements would be helpful for understanding 3-dimensional anatomy. The surgeon would have to work in an area 2- 4.5 cm (considering the range of both the measurements) from the anterior nasal spine.

In our cadaveric study, the distance between anterior nasal spine and M point was an average of 29.93 mm (table-5). Chastain et al in their study , however, reported that M point was approximately 39 mm (95% CI 35.5-42.5 mm) from the nasal sill in women and 48.0 mm (95% CI 44.0-52.0 mm) in men. The reason for our lesser measurement could be because we had done on cadavers and our second point was taken from anterior nasal spine and not the nasal sill (which is a soft tissue measurement). In our study the distance between maxillary sinus ostium to M point was an average of 8.93mm (table 6). This was similar to the report of Chastain et al (25) who reported it to be an average of 10.8 mm.

In our study, the lacrimomaxillary suture was seen posterior to maxillary line in nine (45%); at maxillary line in eight (40%) and anterior to maxillary line in three (15%) of the

cadavers. Orhan et al reported that in 11 out of 16 cadavers, maxillary line lay over lacrimomaxillary suture (69%) and in five cadavers, lacrimomaxillary suture was located anteriorly. Hence, incising the mucosa anterior to maxillary line and elevating it ensures exposure of lacrimomaxillary suture line in majority of cases (1).

In our study maxillary line overlapped the lacrimal sac in 95% cadavers (19 / 20). In one cadaver the lacrimal sac was completely anterior to the maxillary line. Orhan et al (1) reported that maxillary line overlapped the lacrimal sac in 18 of 20 cadavers. Therefore an incision performed anterior to maxillary line could be sufficient to expose lacrimal sac too.

Thickness of lacrimal bone was found to be 0.25 mm in our study. Hartikainen et al reported the mean thickness was 0.106 mm (30). Another cadaver–based study also revealed that the posteromedial aspect of the lower lacrimal sac is covered by lacrimal bone with an average thickness of 0.057 mm.(31) The lacrimal bone at the lacrimal sac fossa is so thin that it can be easily penetrated with most surgical instruments. However in our study, the lacrimal bone was thicker than other studies.

Following removal of lacrimal bone, the lower part of lacrimal sac was seen in 19 cadavers (95%) in our study. This was also noted by Yung et al that in all the cadavers the position of the lacrimal passage covered by the lacrimal bone corresponded to the posteromedial aspect of the upper lacrimal duct and the lower lacrimal sac. (31) In our study we found the distance between posterior edge of lacrimal sac and axilla of middle turbinate was an average of 8.76 mm (table 10) and between anterior edge of lacrimal sac and axilla of middle turbinate was an average of 10.58 mm (table 11). Orhan et al, reported the distance between former and latter to be 4.06 mm and 3.67 mm respectively (1). The reasons for greater distance in our study could be due to the anatomical variation

in the Indian population and presence of agger nasi. However, there was no significant correlation between the dissection and CT measurements. The reasons were

1. Posterior and anterior edge of lacrimal sac is a soft tissue structure and difficult to define in plain CT.

2. Cranio-caudal distance was measured on coronal images and anteroposterior / medio-lateral components of this distance were not included in the CT measurement.

The distance between posterior edge of lacrimal sac and Maxillary sinus ostium was found to be an average of 12.91 mm in our study (table 13). This measurement showed positive correlation with CT scan measurements. The distance between posterior edge of lacrimal sac and ethmoidal bullae was an average of 8.82 mm (table 14) and between inferior edge of lacrimal sac and inferior turbinate was an average of 7.90 mm (table 16) in our study. Orhan et al also reported the distance to be an average of 7.93 mm and 8.25 respectively (1). In our study the anteroposterior diameter of lacrimal sac was an average of 7.35 mm (table 17) similar to Orhan et al, who reported it to be an average of 7.62 mm. However, there was no significant correlation to CT measurements. The length of lacrimal sac in our study was an average of 11.72 mm (table 18) and this showed positive correlation with CT scan measurements. Orhan et al also reported the length of lacrimal sac was of 12.76 mm. Groell et al in their CT scan study reported that the mean length of the nasolacrimal sac was 11.8 +/- 2.5 mm.(20) In our study the distance between fornix (superior end) of lacrimal sac and axilla of middle turbinate was of 8.88 mm (table 19). This showed positive correlation with CT scan measurements. However, Orhan et al, reported the distance between fornix of lacrimal sac and axilla of middle turbinate to be 4.73 mm.(1)

In our study the distance between fornix (superior end) to maxillary sinus ostium was of an average of 19.66 mm (table 20). This showed positive correlation with CT scan. This has not been previously reported. In our study the distance between the anterior nasal spine and fornix of lacrimal sac was an average of 40.54 mm (table 21). There was no significant correlation to CT measurements. Orhan et al also reported the distance between anterior nasal spine and fornix of lacrimal sac was an average of 41.20 mm. (1)In our study the distance between anterior nasal spine and inferior edge of lacrimal sac was an average of 32.26 mm(table 22), similar to Orhan et al, who reported it to be an average of 31.36 mm. (1)

More than half of the lacrimal sac was above the axilla in 60% and less than half above the axilla in 40 % of cadavers in our study (seen both in dissection and CT scans). This is similar to studies done by various authors. (2) (1) Exposure of the part of lacrimal sac above the axilla was difficult in our study as frontal process of maxilla was thick in that portion. During ENDO-DCR also it is difficult to remove this bone as the bone is thick and access to the area is difficult. However to ensure adequate exposure, removing bone by drill is a promising option. (57) A large opening into the sac extended inferiorly to level of M point resist stenosis and may also avoid lacrimal sump syndrome. (25)

In our study nasolacrimal duct passed superiorly and anteriorly from the orifice to the direction towards axilla and was on average of 10.27 mm in length (table 28). This showed positive correlation with CT scan measurements. Lin et al reported that length of nasolacrimal length was an average of 14.14 mm. (33) Groell et al did CT examination in 147 patients and demonstrated that the mean length of the nasolacrimal duct was 11.2 +/- 2.6 mm; the narrowest diameter was 3.7 +/- 0.7 mm.(20)

NLD was about 4.04 mm anterior to maxillary sinus ostium in our study. Tatlisumak et al also reported this distance as an average of 3.9 mm.(24) So care should be taken while enlarging maxillary sinus ostium anteriorly.

The anterior nasal spine and anterior attachment of the inferior nasal concha are reported landmarks to localize NLD.(24). In our study the intranasal orifice of the NLD was located an average of 25.27 mm away from the anterior nasal spine and as an average of 14.74 mm away from the anterior attachment of the inferior nasal turbinate.

Tatlisumak et al (24) reported that the intranasal orifice of the NLD is located approximately 24.6 mm away from the anterior nasal spine and 14.3 mm from the anterior attachment of the inferior nasal turbinate. Ni et al (33) reported that the intranasal orifice of the NLD is located approximately 29.0 mm away from the ANS and 11.7 mm from the anterior attachment of the inferior nasal turbinate.

In our study the genu was noted at NLD in 45% of cases, posterior to in 50% of cases and anterior in 1 case (because of concha bullosa). This has not been previously reported. So incision anterior to level of the genu is sufficient for ENDO-DCR.

In our study agger nasi was noted in 16 cases (80%), adjacent to the lacrimal fossa **(fig.22)**. Woo et al also reported it to be 77.6% in their study. (29) Agger nasi can be encountered anterior to middle turbinate and might lead to confusion in searching of nasolacrimal sac.(58) Preoperative endoscopic evaluation would suggest its presence and CT scan would be useful in confirming this.

Most of the oblique dissection measurements did not correlate with CT measurements as it was possible to take CT measurements, only in one or two planes (cranio-caudal / anteroposterior / mediolateral)

Conclusions

1. The distance between the anterior nasal spine and genu was noted to be 28.15 mm (19.98-37.21) by dissection and that between the anterior nasal spine and axilla was noted as 34.89 mm (23.64-44.40) by dissection. Both these showed a positive correlation with CT measurement. The surgeon who is considering ENDO –DCR, would have, hence to work in an area 2- 4.5 cm approximately (considering the range of both the measurements) from the anterior nasal spine. This has not been previously reported.

2. The maxillary line: the first landmark in ENDO-DCR

a) Maxillary line (a curvilinear, mucosal eminence from axilla to dorsum of inferior turbinate) was present in 75% for the cadavers. In those with unclear maxillary line, a ridge was always present on the superior surface of inferior turbinate, near it's medial border and an imaginary line, drawn from anterior end of this ridge to axilla could represent the maxillary line. This, in turn, would assist the surgeon to initiate the ENDO DCR; this has not been previously reported

b) Incision performed anterior to the maxillary line could be sufficient to expose the lacrimal sac as:

i. The lacrimomaxillary suture was seen posterior to or at the maxillary line in majority of the cadavers, with 15%, being anterior to the line.

ii. The maxillary line overlapped the lacrimal sac in 95% cadavers (19 / 20) and in one cadaver the lacrimal sac was completely anterior to the maxillary line.

3. **M Point: the second landmark**

"M point" marked the level of superior aspect of the maxillary sinus ostium, and the junction of the lacrimal sac and the nasolacrimal duct anteriorly in all cadavers. Hence it is to be used as an inferior limit of surgical exposure of lacrimal sac.

4. **Axilla:** third landmark

In all the cadavers the lacimal sac was above the axilla (more than half of the sac in 60% of cases and less than half in 40 %) by both dissection and CT scan measurements..The distance between fornix of lacrimal sac and axilla of middle turbinate was of average 8.88 mm and this showed positive correlation with CT scan measurements. Hence as described in literature starting the incision 8-9 mm above axilla and 8-9 mm anterior to axilla ensures complete exposure of lacrimal sac.

5. To expose the part of lacrimal sac above the axilla was difficult in our study as frontal process of maxilla was thick in that portion. Hence to ensure adequate exposure, removing bone by drill appears to be necessary option.

6. Regarding Nasolacrimal sac (NLD)

i. NLD was about 4.04 mm anterior to maxillary sinus ostium. This has not been previously reported in Indian cadavers. So extreme care need to be taken while enlarging ostium anteriorly

ii. The Genu was noted at NLD in 45%, posterior to in 50% and anterior in 5% cadavers. The one cadaver where it was anterior it was because of the presence of concha bullosa. This has not been previously reported. This also supports that incision anterior to level of the genu is sufficient for ENDO-DCR.

7. Agger nasi was noted in majority of the cadavers. Agger nasi can be encountered anterior to middle turbinate and might lead to confusion in searching of nasolacrimal sac. Preoperative endoscopic evaluation for the presence of aggar nasi is mandatory in all cases prior to ENDO-DCR. In doubtful cases, following endoscopy / revision DCRs, CT scan is indicated.

8. CT scan appears to be also useful in measuring length of lacrimal sac and nasolacrimal duct.

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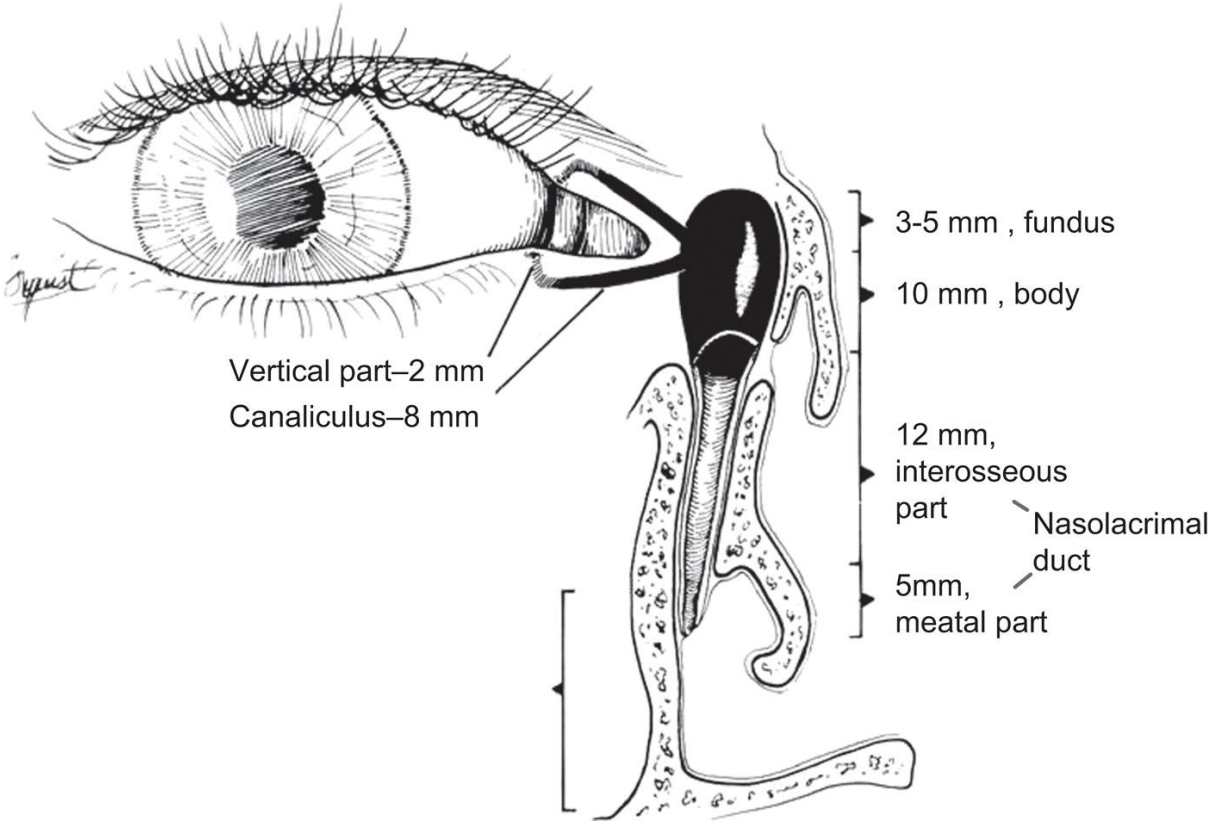
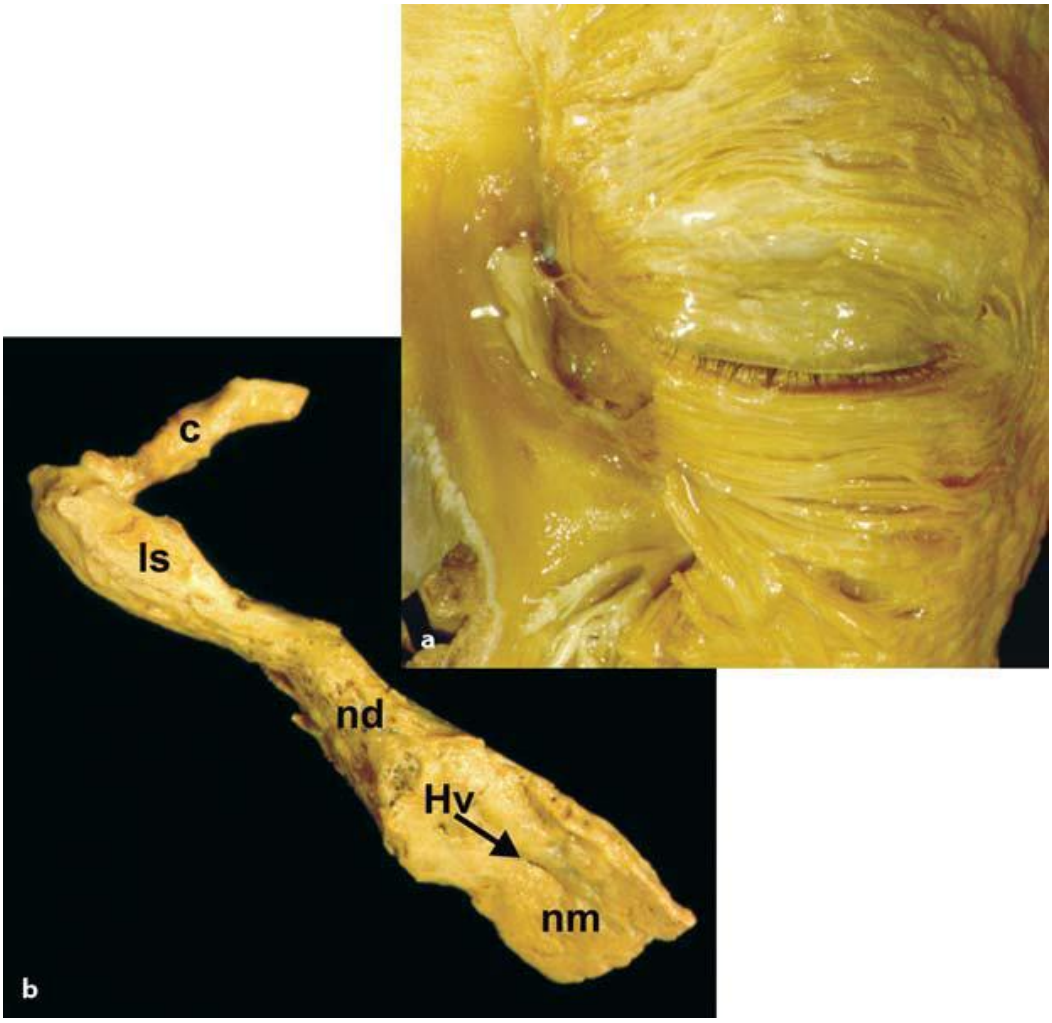
Figure 1



Anatomy of Nasolacrimal Drainage System. (17)

Figure 2

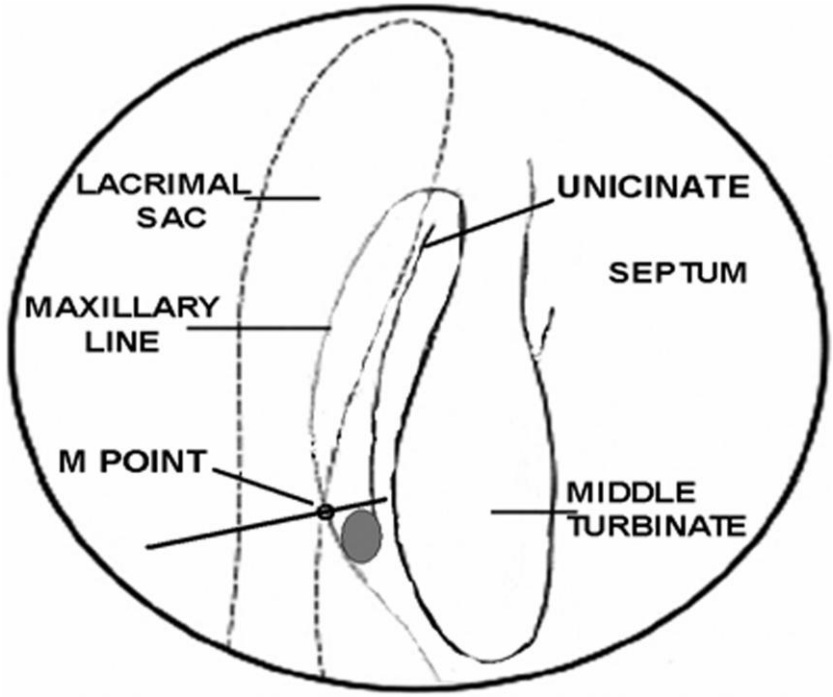


Macroscopy of the nasolacrimal ducts

a. View of a prepared lacrimal system in situ (Anatomical collection of the Christian Albrecht University of Kiel, Germany)

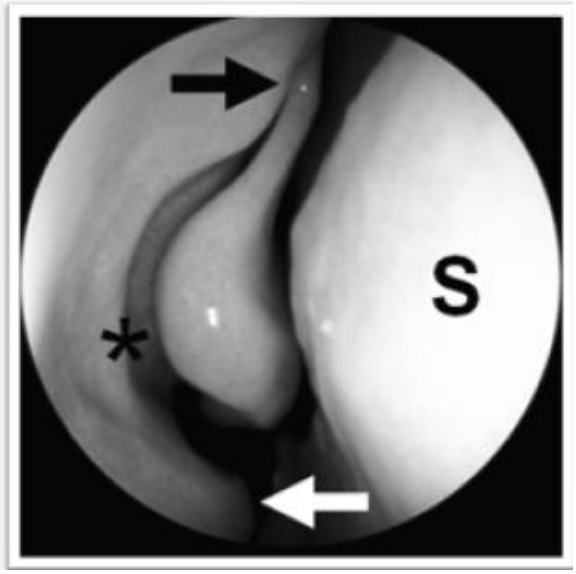
b. Macroscopic view of a prepared nasolacrimal system removed from its bony canal. *c* Lacrimal canaliculi (individual canaliculi not distinguishable), *ls* lacrimal sac, *nd* nasolacrimal duct, *nm* mucous membrane of the nose, *hv* area of Hasner's valve opening of the nasolacrimal duct into inferior meatus of the nose. (18)

Figure 3



Endoscopic view of the right nasal cavity. An axial line through the M point is approximately at the level of the superior margin of the maxillary ostium posteriorly and just below the lacrimal sac-duct junction anteriorly. (25)

Figure 4



Endoscopic view of the right lateral nasal wall in a live subject

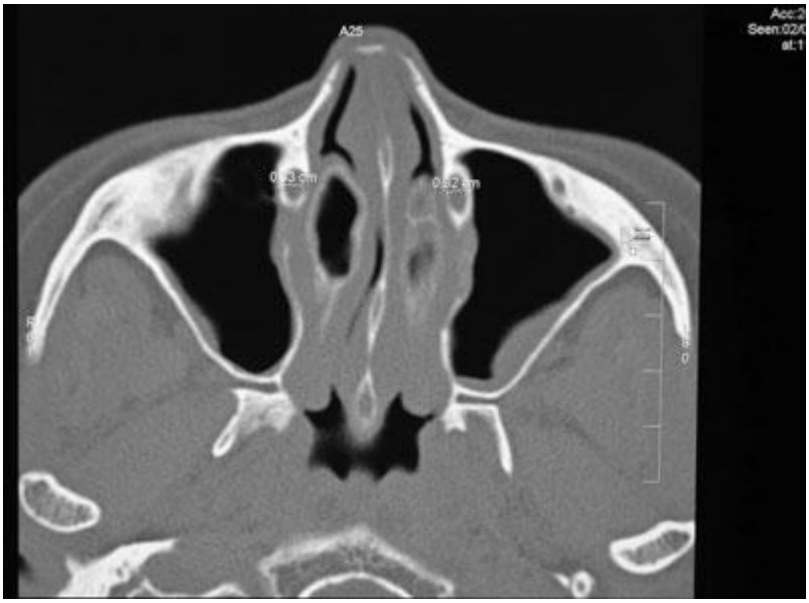
The curvilinear maxillary line; *

Axilla ; *black arrow*

Root of the inferior turbinate; (*white arrow*)

Septum; S (25)

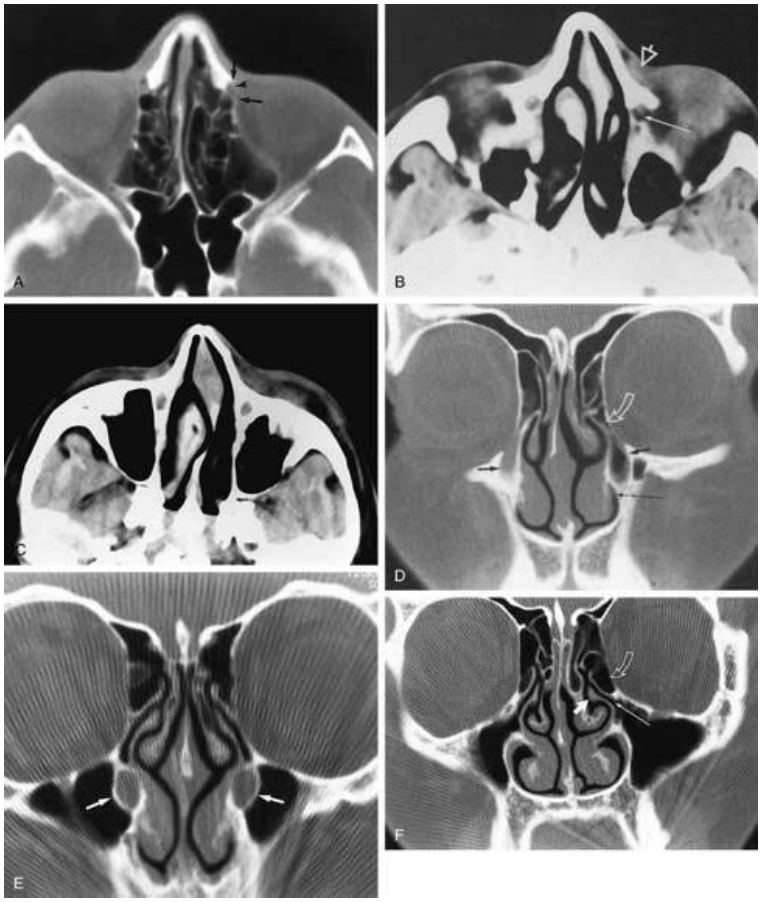
Figure 5 - Nasolacrimal duct



Axial computed tomography image from a sinus scan series.

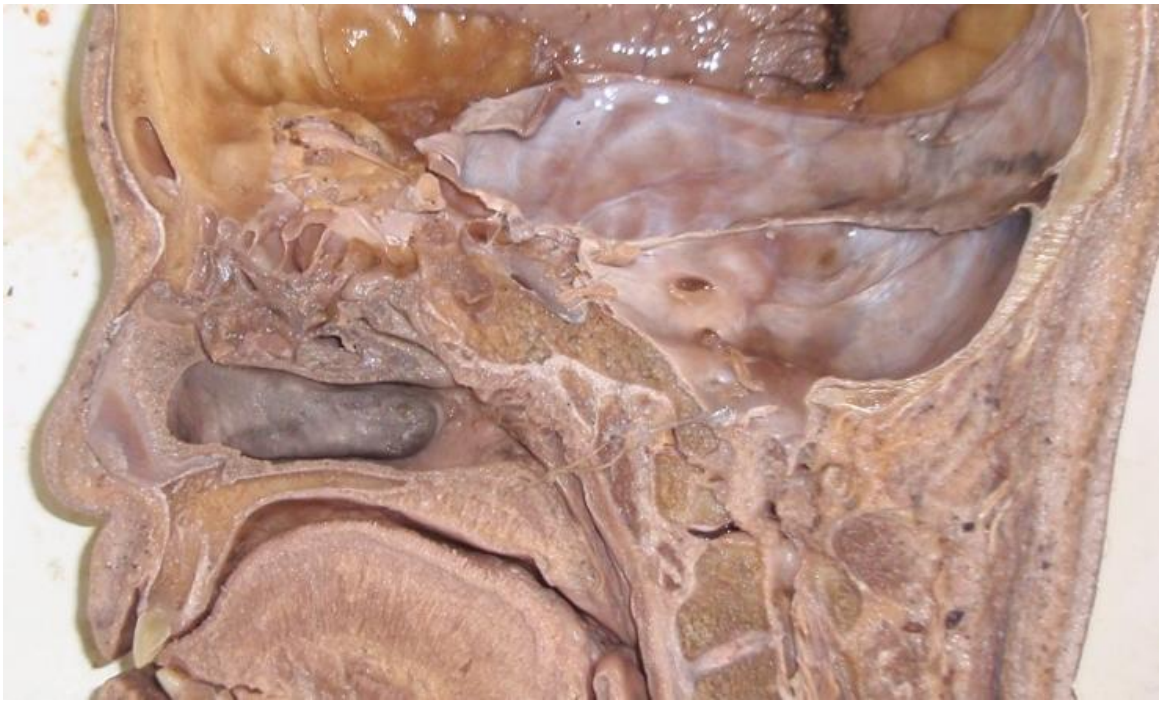
Air within the NLDS as a normal variant. **A**, Distended left nasolacrimal duct (*oblique arrow*) with air extending to the valve of Hasner (*vertical arrow*). Air also in the right lacrimal sac (*horizontal arrow*). Ethmoid agger nasi (*e*) immediately medial to the superior aspect of the lacrimal sac. **B**, Bilateral air-filled lacrimal sacs (*arrows*). Note the relationship of the anterior ethmoid air cells (agger nasi) (*e*) and its importance in DCR planning. (41)

Figure 6



Normal CT anatomy. **A** to **C**, Axial. **A**, High-resolution axial CT scan shows the nasolacrimal fossa (*arrowhead)* and anterior and posterior lacrimal crests (*arrows*). **B** and **C** preseptal lymphoma of the left orbit, noted as a soft-tissue density (*open arrow* in **B**) on both images. **C**, One slice, more inferiorly, is unable to define the nasolacrimal duct within the nasolacrimal canal. . **D** to **F**, Coronal. **D**, Nasolacrimal canal (*short arrows*) is seen bilaterally lateral to the middle meatus and is directed inferiorly toward the inferior meatus (*thin arrow*). **E**, Nasolacrimal canals are oriented posteroinferiorly from superior to inferior. **F**, Just posterior to the nasolacrimal canal, a coronal image shows the osteomeatal unit. Ethmoid bulla (*open arrow*), infundibulum (*thin arrow*), and uncinate process (*short arrow*) are seen. (44)

Figure 7



Sagittal head section (right)

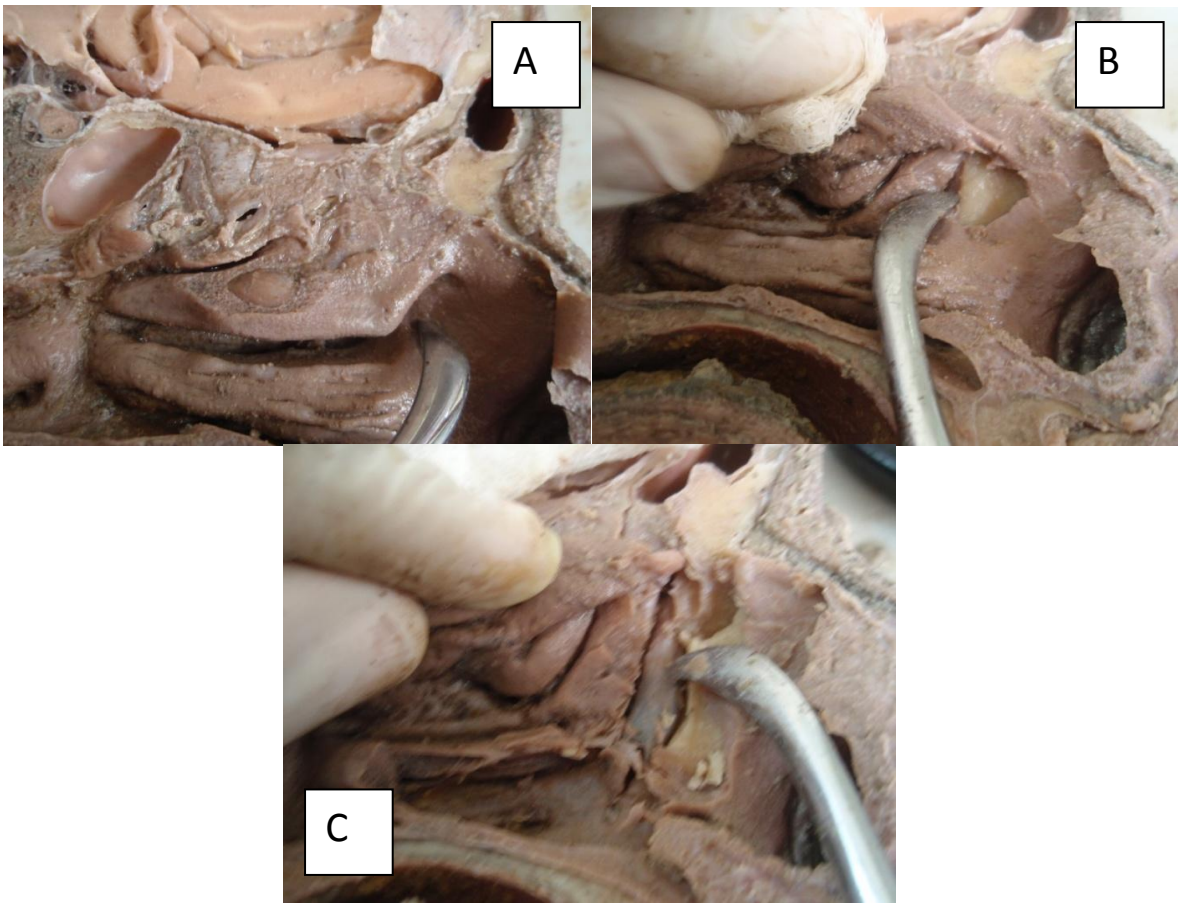
Figure 8

Plain CT-PNS of 10 cadaver's head sections (paranasal sinuses, 0.8 mm axial sections with 0.4mm overlap) were done.

Figure 9

Digital calliper

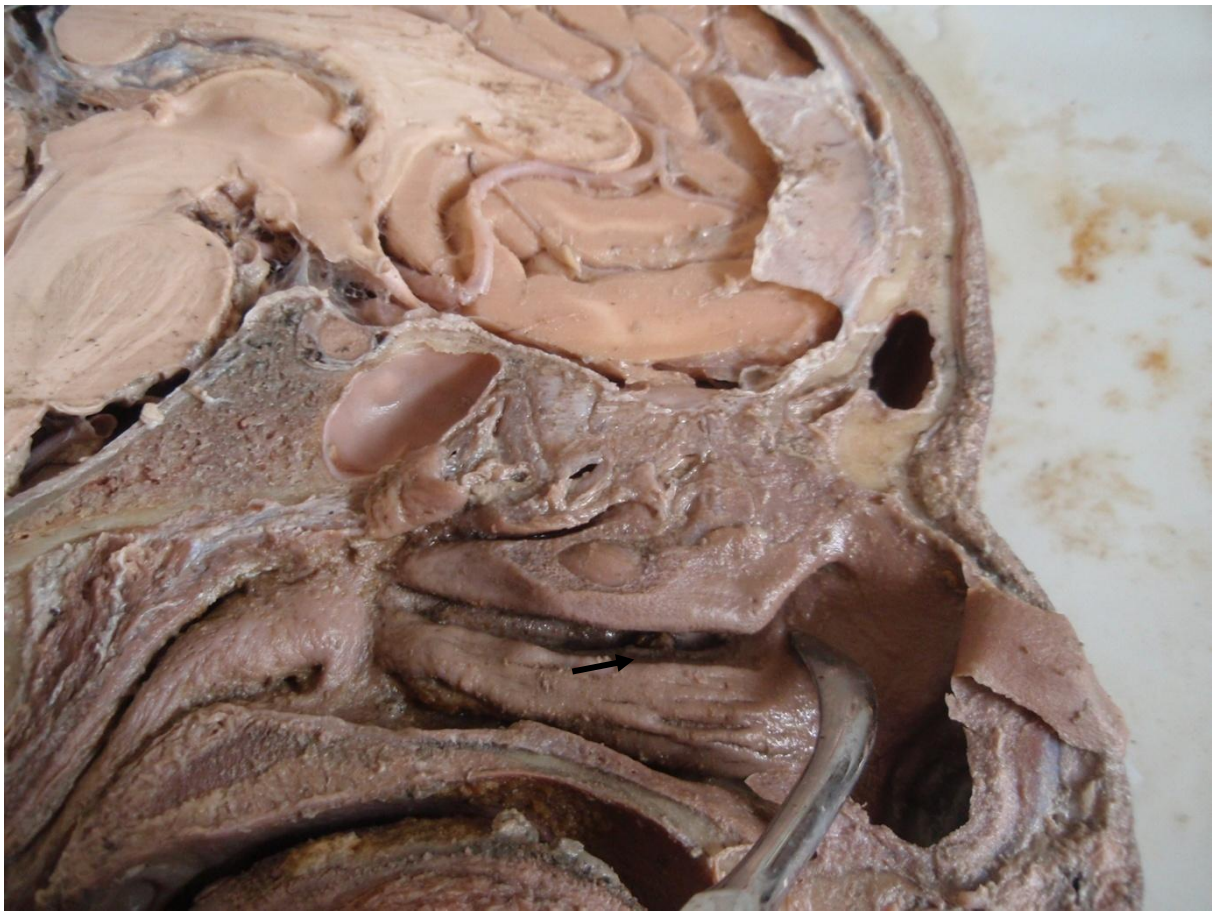
Figure 10



A-Maxillary line, B-Removing frontal process of maxilla

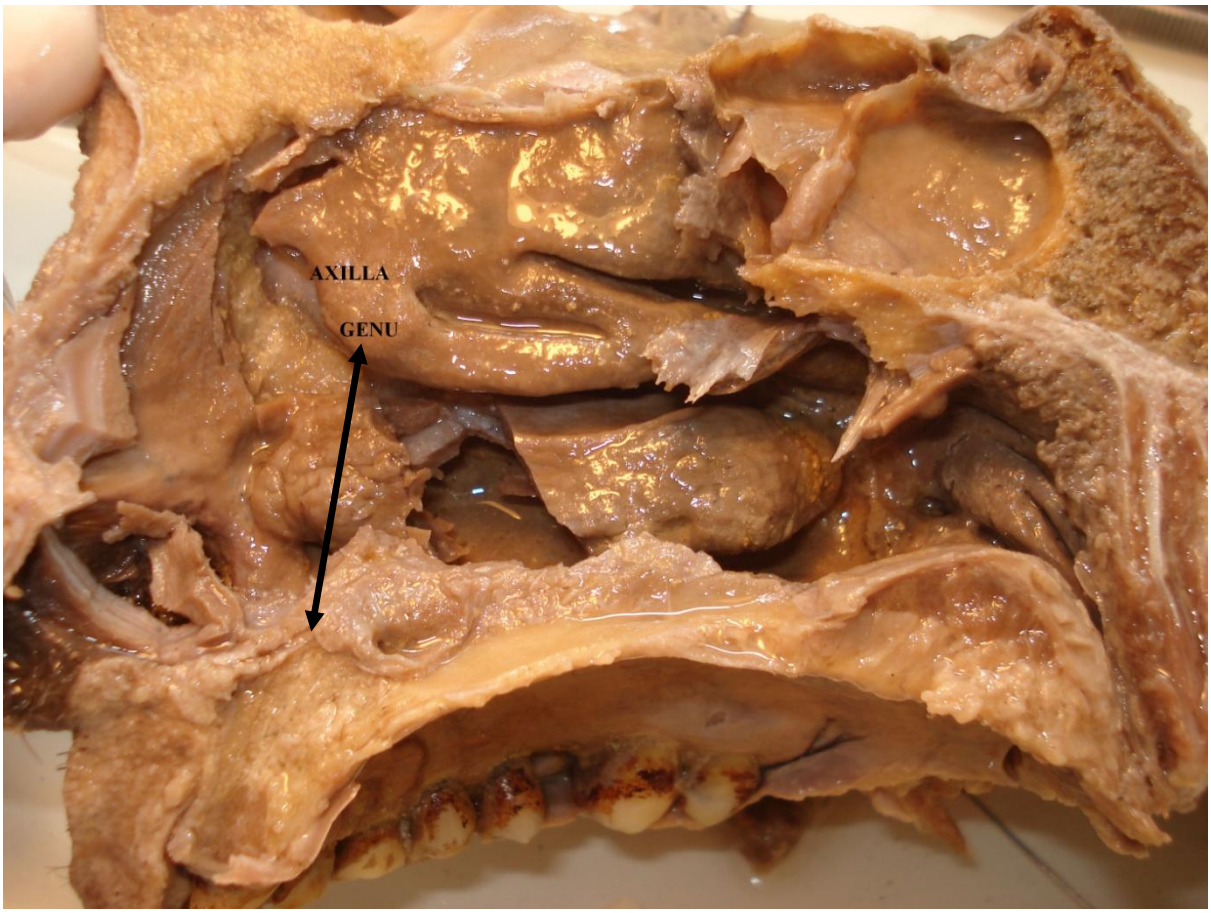
C- Exposed lacrimal sac and duct

Figure 11



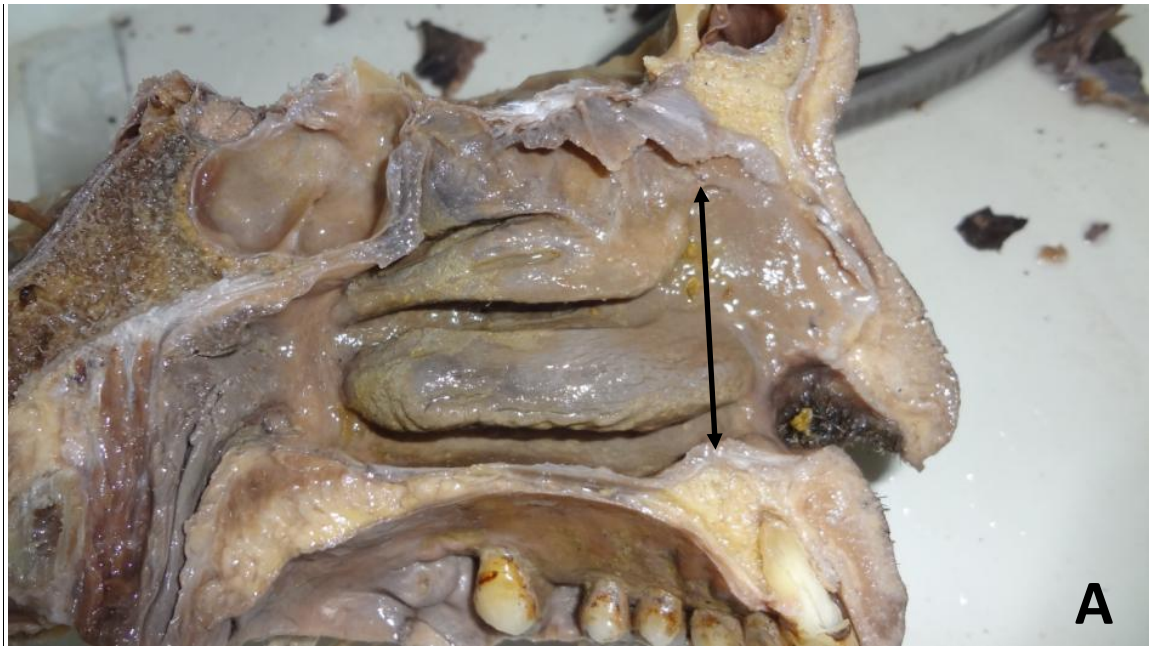
In those with unclear maxillary line, a ridge was always present on the superior surface of inferior turbinate, near it's medial border and an imaginary line, drawn from anterior end of this ridge to axilla could represent the maxillary line.

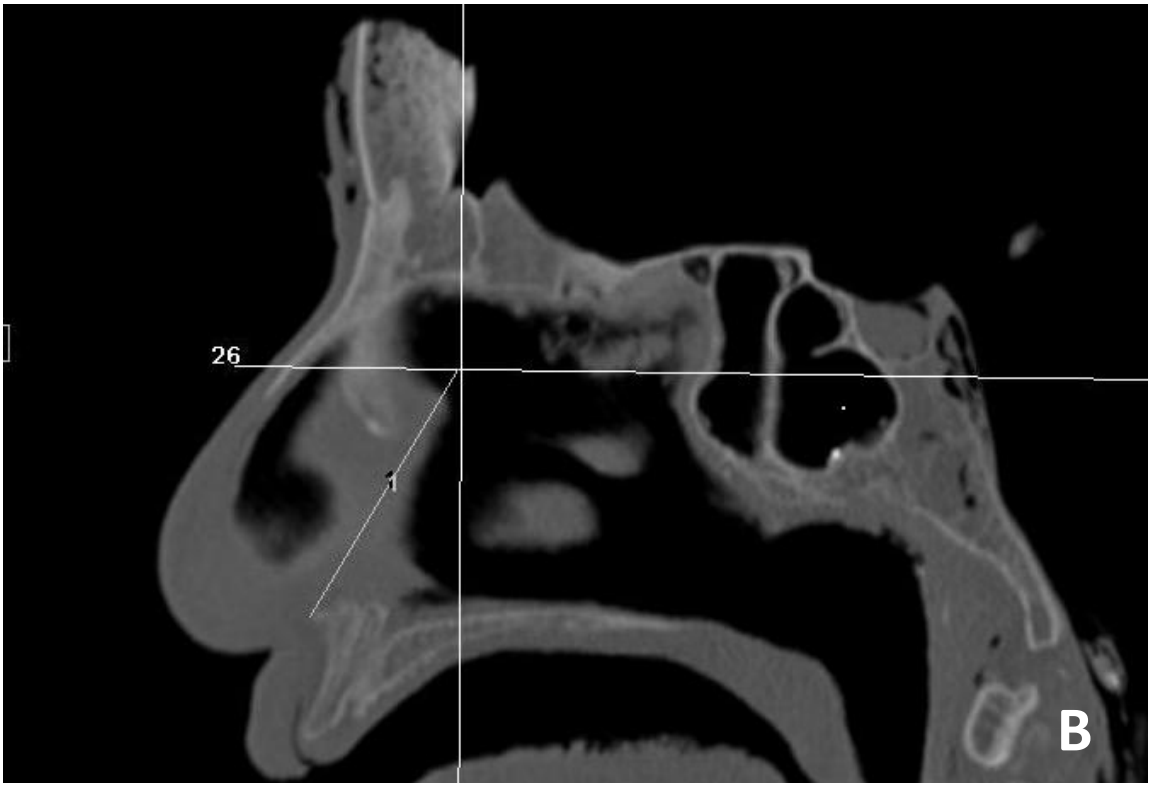
Figure 12



Dissected specimen depicting axilla and genu: double arrow shows ANS to genu

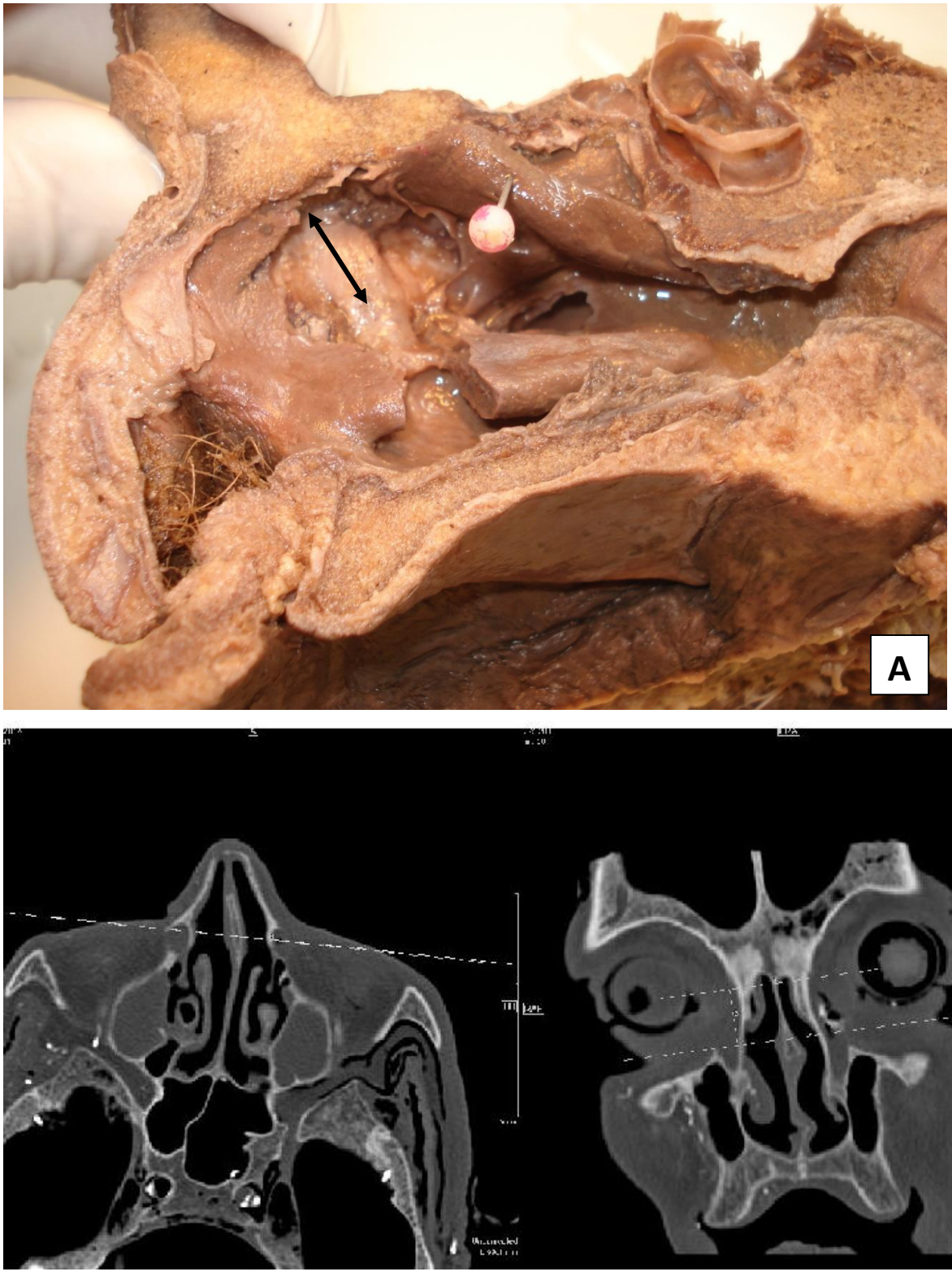
Figure 13





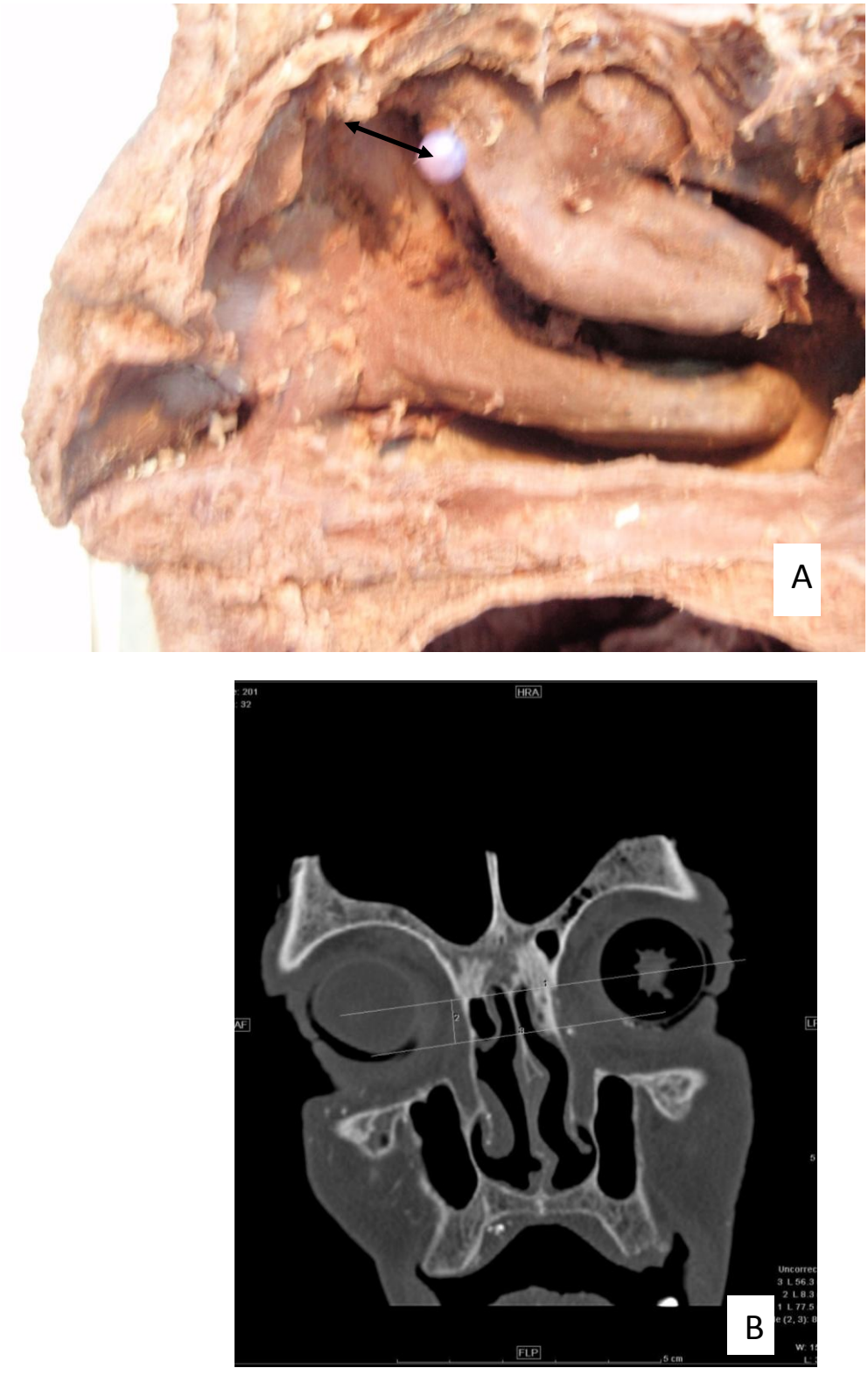
Anterior nasal spine to axilla- A- cadaver dissection (double arrow) B- CT scan sagittal section (1)

Figure 14



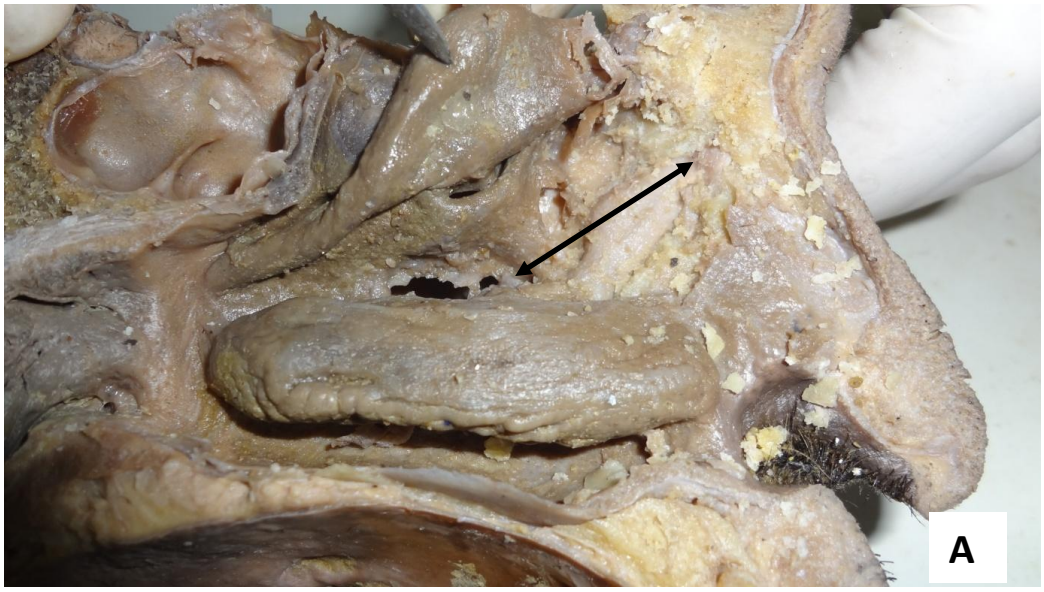
Length of lacrimal sac: A: cadaver dissection (double arrow) B: measurement by axial and coronal section

Figure 15



Fundus of lacrimal sac to axilla: A: cadaver dissection (double arrow) B: Coronal CT scan (2)

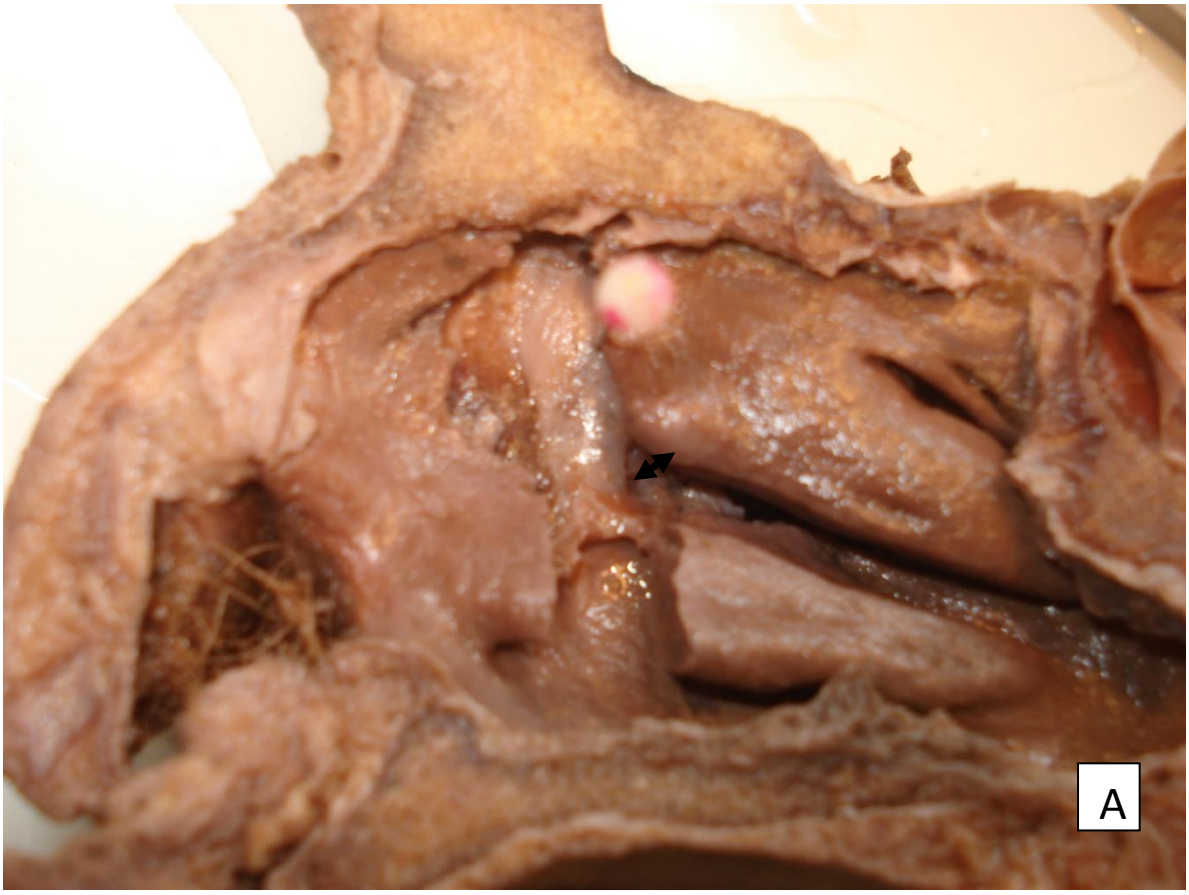
Figure 16

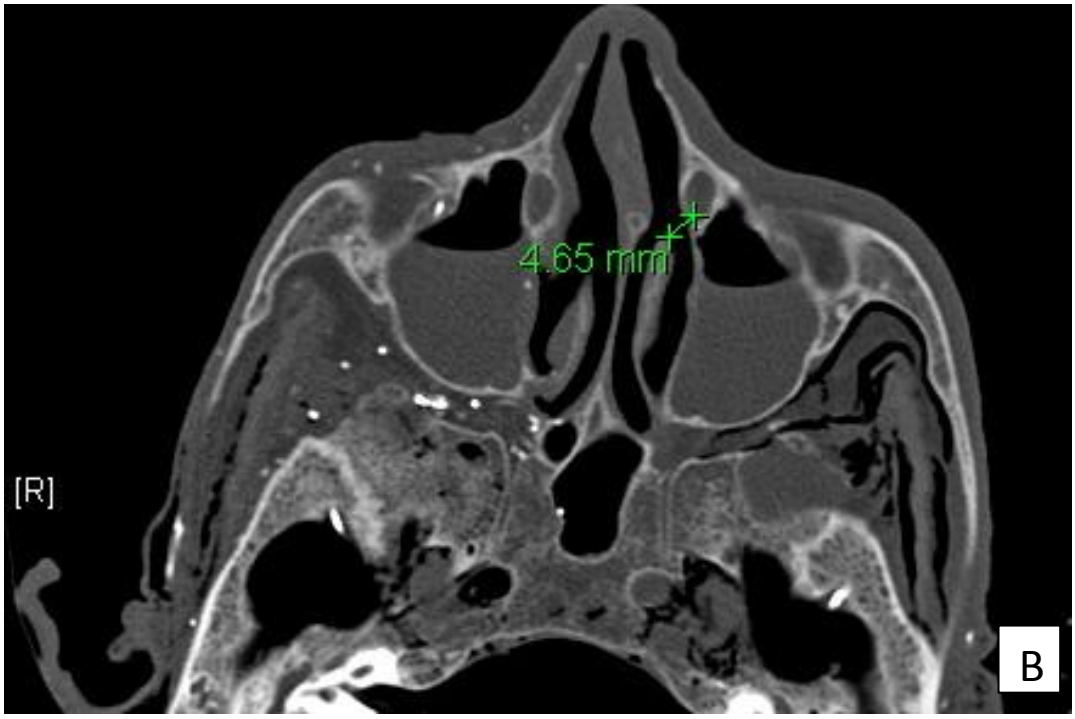


Fundus to maxillary sinus ostium A- Cadaver dissection (Double arrow)

B-Coronal CT scan (2)

Figure 17

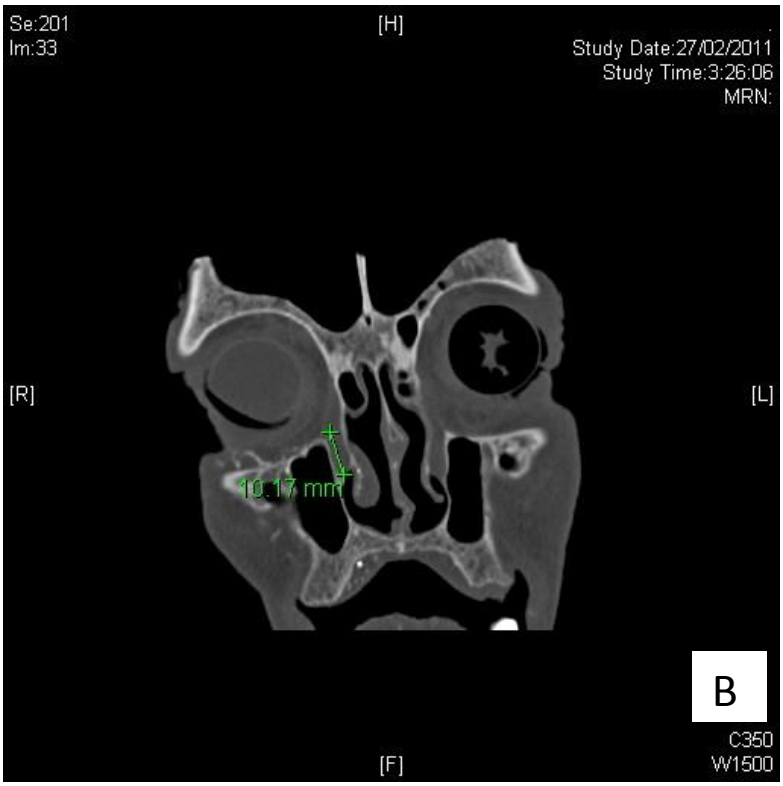




Nasolacrimal duct and genu: A- Cadaver dissection (double arrow),

B-Axial CT section

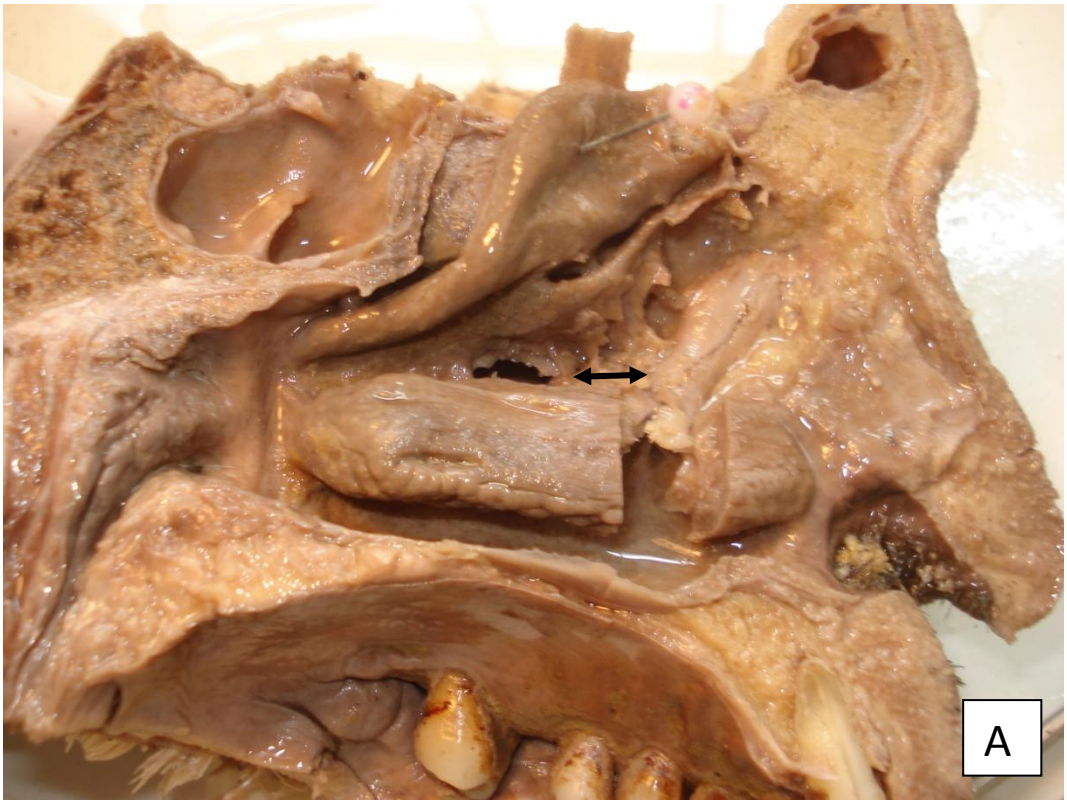
Figure 18

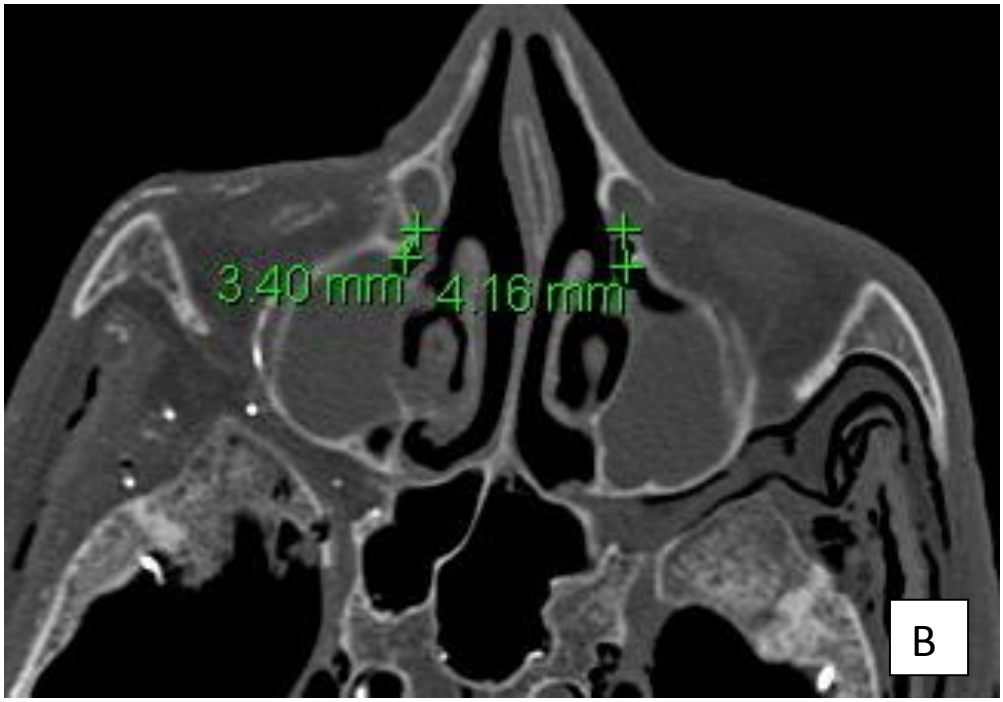


Length of nasolacrimal duct: A-Cadaver dissection (double arrow)

B-Coronal CT scan

Figure 19

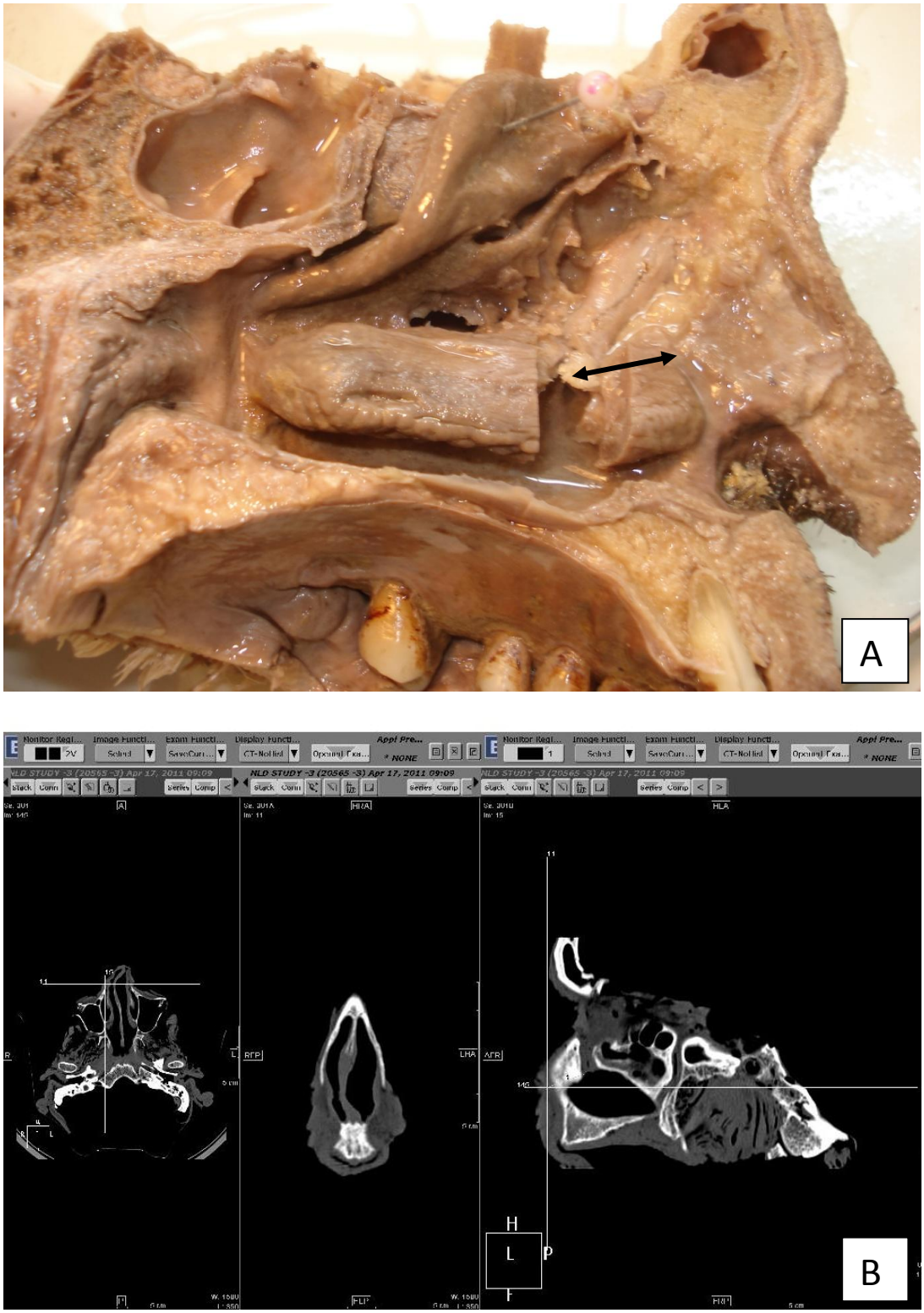




Nasolacrimal duct to maxillary sinus ostium: A-Cadaver dissection (double arrow)

B-Axial CT scan

Figure 20



Anterior end of inferior turbinate to intranasal orifice of nasolacrimal duct

A. Cadaver dissection (double arrow); B. CT scan

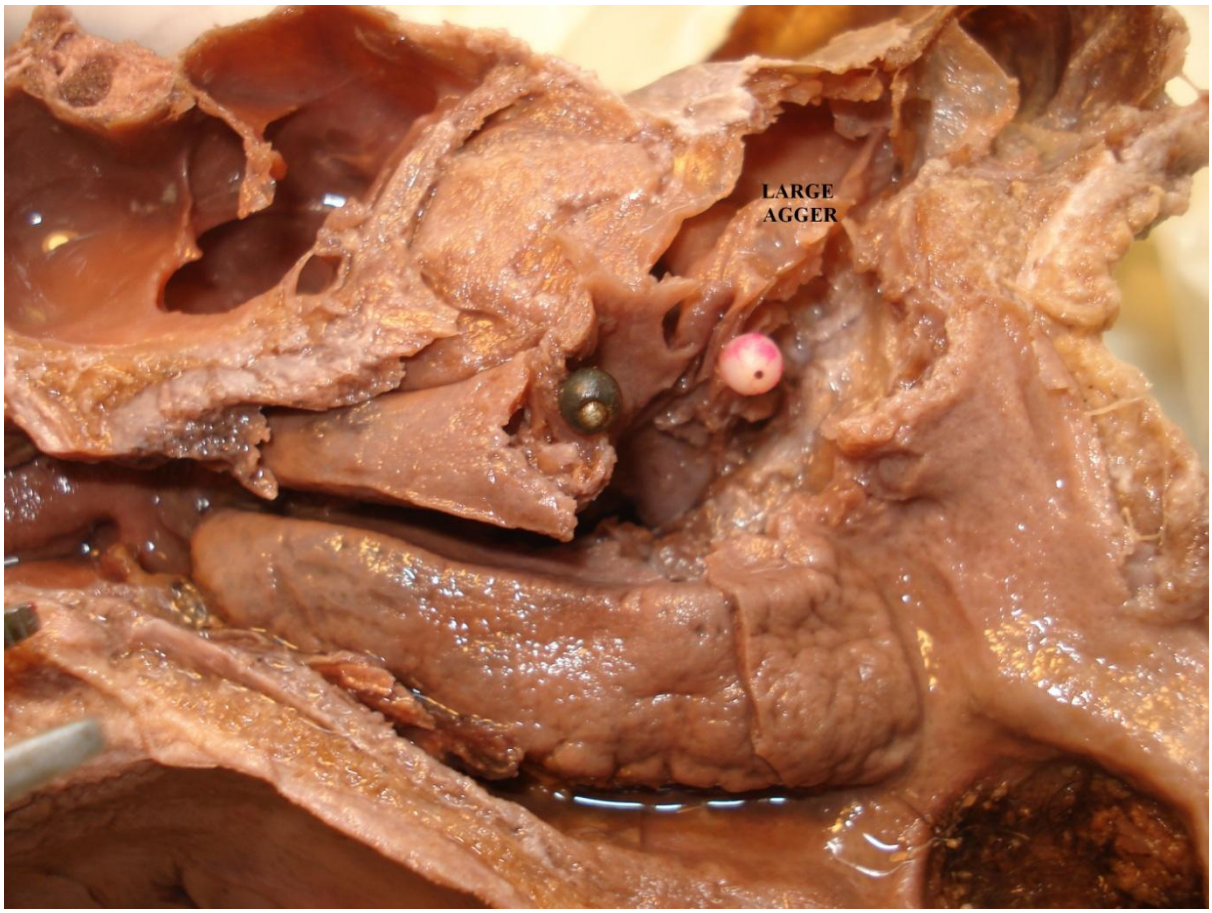
Figure 21

SAGITTAL HEAD SECTION: Lower violet pin -Anterior nasal spine

Middle violet pin -M point

Blue pin-Axilla

Figure 22



Dissected specimen depicting large Agger nasi

CT PROFORMA

1.
2.
3. Distance from
    a) Anterior nasal spine to most anterior point of middle turbinate
    b) Anterior nasal spine to axilla of middle turbinate
    c)
    d)
4.
5. Thickness of lacrimal bone
6.
7. Distance between
    a) Posterior edge of lacrimal sac and axilla of middle turbinate
    b) Anterior edge of lacrimal sac and axilla of middle turbinate
    c) Posterior edge of lacrimal sac to anterior most point of middle turbinate
    d)
    e) Posterior edge of lacrimal sac and maxillary sinus ostium
    f)
8. Superior end of sac (at / below/ above axilla)
9.
10. Anteroposterior diameter of lacrimal sac
11. Length of lacrimal sac
12. Distance between
    a) Fornix of lacrimal sac and axilla of middle turbinate
    b) Fornix to ostium
    c) Anterior nasal spine and fornix of lacrimal sac
    d)

13. The relationship between the lacrimal sac and the axilla of the middle nasal concha.

14.

15.

16. Relation of anterior point of middle turbinate to nasolacrimal duct:(at/anterior/posterior
17. Nearest distance between genu and duct
18. Length of the nasolacrimal duct (from the transition area between the sac and duct up to the intranasal orifice)
19. Nearest distance from the
    a) Nasolacrimal duct to the maxillary sinus ostium
    b) The Nasolacrimal duct to the anterior nasal spine
    c) Intranasal orifice of the nasolacrimal duct to the nasal floor
    d) Intranasal orifice of the nasolacrimal duct to anterior attachment of the inferior turbinate.
20. Fornix to ostium
21. Genu to duct

ID NO.	LR	ML	Lt.ML	ANS-GENU	CTANS-GENU	ANS-AXILLA	CTANS-AXILLA	ANS-Mpt.	MSO-Mpt.	LMSL-ML	LB	CTLB	LBr-LS	Lspos-Ax	CTLspos-Ax
90-1	R	1	14.43	33.69	30	41.23	34	37.18	7	3	0.3	0.5	1	9.53	6.6
90-1	L	1	15.36	34.82	31	37.58	33.7	26.89	7.02	2	0.25	0.4	1	7.56	5.7
91-2	R	1	9.67	25.67	24.4	33.04	31	24.95	7.5	2	0.23	0.4	2	8	7.5
91-2	L	1	8.09	27.92	23	34.84	33	29.89	6.45	1	0.21	0.4	1	9.5	8.8
85-3	R	1	14.28	35.98	24.6	44.4	35.7	39.42	11	3	0.23	0.4	1	7.99	8.85
85-3	L	1	14.24	37.21	27.9	42.97	35.7	38.19	11.14	3	0.22	0.4	1	7.75	7.5
87-4	R	1	14.8	32.54	31.7	37.09	35.2	35.3	9.8	1	0.27	0.4	1	7.44	7.2
87-4	L	1	11.15	24.26	21.3	33.84	31	30.12	7.25	1	0.3	0.4	1	6.02	11.3
88-5	R	1	12.2	29.39	27	34.35	32	28.97	9	3	0.15	0.4	1	9.45	9.5
88-5	L	1	11.01	29.8	27.3	33.95	31.5	31.72	8.36	3	0.25	0.4	1	9.7	9.8
98-6	R	1	10.73	23.25	21	29.68	27.4	24.36	6.24	2	0.34	0.5	1	8.21	8.2
98-6	L	2	12.92	27.02	25.3	36.02	33.5	32.8	7	2	0.28	0.4	1	12	8.9
94-7	R	1	14.48	26.13	25.1	32.77	31	26.78	9.1	3	0.25	0.4	1	9.18	10
94-7	L	1	13.6	30.74	27.9	38.39	36.4	33.34	11.27	2	0.27	0.4	1	9.92	7.2
89-9	R	2	9.59	22.34	20	30.51	28.8	26.57	8.55	3	0.14	0.4	1	10.83	11.6
89-9	L	2	8.78	25.12	22	30.21	27.9	26.81	9.12	3	0.15	0.4	1	10.6	10.4
49-10	R	2	15.82	29.14	28.9	37.96	32.7	30.77	9.51	2	0.35	0.5	1	8.96	5.9
49-10	L	1	16.79	26.11	25.9	37.7	34.9	30.7	12.41	2	0.33	0.5	1	9.55	7.8
100-11	R	2	10.89	21.8	20	27.55	26.8	23.58	9.67	2	0.22	0.4	1	6.29	8.3
100-11	L	1	11.9	19.98	17.5	23.64	21.1	20.25	11.3	2	0.19	0.4	1	6.8	9.3

Lsant-Ax	CTLsant-Ax	LSpos-GENU	CTLSpos-GENU	lSpe-MSO	CTlSpe-MSO	Lspe-EB	Lsse	CTLsse	Lsie-IT	LSap	CTLSap	LSlt.	CTLSlt.	Lsfo-Ax	CTLsfo-Ax
11.04	8	9.72	9	9.5	9	8.57	1	1	6.88	9	5.5	12.75	13.5	9.93	6.3
13.44	7	8.5	8	9.6	9.2	8.6	1	1	8.59	7.78	5.5	12.69	15.4	8.85	4.2
12	11.3	9	8.5	10	9.5	9.19	1	1	7.73	6.37	5	7.48	11	7.46	4.5
10.09	12.4	9.5	9	9.6	9	10.63	1	1	6.37	5.71	6.5	6.98	10.5	8.83	5
9.7	9.3	9.85	12.9	8.22	10.6	8.1	1	1	7.77	8.01	6.6	11.23	13	6.67	6.6
10.37	8.1	12.01	8.6	11.8	10.6	6.85	1	1	7.07	6.1	6.3	12.13	11.3	7.46	4
7.65	7.9	10.4	8.8	18.02	14.5	7.53	1	1	8.92	7.1	7.9	10.82	11.3	5.43	5
6.33	12.4	13.98	12.7	15.57	11.5	9.74	1	1	8.79	5.54	5.6	12.32	10.5	5.97	5.5
10.43	10.5	15.31	13.5	14.4	13.6	11.9	1	1	6.97	6.83	5.6	12	12.9	12.2	7.7
11.24	10	11.42	11.6	14	13.6	5.51	1	1	7.73	9.07	7	10.33	11.5	8.88	7.6
10.09	9.8	14.41	9.5	11.34	12.1	7.52	1	1	7.06	5.84	6.6	11.68	13.3	6.48	7
12.6	10.2	19.22	17	18.28	12.9	8.57	1	1	7.89	6.82	5.8	15.54	13.7	12.57	8.6
10.78	10.9	15.11	14.3	14.86	11.6	6.08	1	1	7.42	6.67	5.5	10.58	12..1	10.3	7.1
11.48	7.8	14.09	16.4	12.8	11.5	8.02	1	1	9.16	6.35	5.1	9.91	12.6	13.32	9.3
10.9	12.3	17.07	9	14.17	9.2	13	1	1	7.56	6.09	9.8	10.82	12.2	10.3	6.1
11	12.3	14.5	9	15.27	9.1	12.57	1	1	7.05	6.67	6.7	13.39	12.2	7.46	8.5
10.48	8.3	12.49	8.8	12.5	10.8	8.35	1	1	8.43	10.58	6.9	13.53	12.2	8.94	4.4
11.31	10	14.53	11.2	12.45	9.8	5.64	1	1	10.47	10.07	8	15.44	13.2	9.23	6
10.03	9.3	12.25	11.2	10.53	9.1	10..85	1	1	8.55	8.81	8.7	11.84	10.7	7.09	3.2
10.55	10	14.97	11.4	13.16	10	9.24	1	1	7.64	7.66	8.4	12.97	11	10.29	3.6

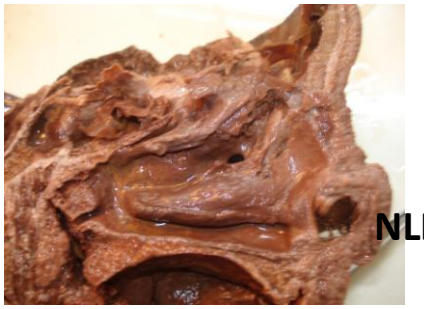
fo-MSO	CTfo-MSO	ANS-LSFfo	CTANS-LSFfo	ANS-Lsie	LA#Ax	CTLA#Ax	LS#ML	NLDpe-EB	GEN#NLD	CTGEN#NLD	GENU-NLD	CTGENU-NLD	NLD	CTNLD
18.76	14.2	45.9	22.6	35.15	1	1	2	9.18	3	3	11.35	8.9	7.06	8
16.98	12.2	39.37	18.5	34.4	1	1	2	8.84	3	3	10.02	7.1	7.5	9
16.12	12	36.95	41.2	30.12	2	2	2	10.5	3	3	4.87	5	14.44	13
17.15	12.5	41.61	37.7	35.43	2	2	3	11.09	3	3	7.63	7	11.13	11.8
16.12	16.4	48.63	43	40.02	1	1	1	9.62	2	2	5.79	8	7.99	9.4
19.3	13.5	48.75	40.06	39.65	1	1	1	8.2	3	3	9.74	8	8	9
19.98	13.4	44.76	40	34.27	2	2	2	8.15	3	3	4.83	3.5	9.22	10.9
22.1	15.4	39.13	37.2	29.02	2	2	2	12.25	1	1	6.07	4.9	9.4	10.2
21	16.7	43.2	37.2	35.24	2	2	2	12.6	2	2	7.68	5.2	9.5	10.5
17.17	15.6	35	35.5	29.37	2	2	2	9.63	3	3	6.87	6.2	9	10.4
17.72	16.8	37.15	33.6	26.8	1	1	2	5.49	2	2	8.14	5.5	5.41	9.1
25	20.2	39.46	36	30.2	2	2	1	7.33	2	2	7.26	6.3	8.57	10.06
21.12	15.3	38.09	36.8	29.29	2	2	3	6.09	3	3	8.81	6.4	9.47	10.3
22.18	15.4	40.72	37.3	33.02	1	1	1	6.54	3	3	7.23	8.8	12.28	11.5
17	13.2	39.56	37.2	31.12	2	2	2	13.16	2	2	6.17	5.5	15.54	14.9
21.6	15.2	41.91	39	33.45	2	2	2	13.25	2	2	6.5	6.2	15.84	13.9
20.82	14.7	44.96	37.1	37.5	1	1	1	5.15	3	3	10.24	7.6	12.3	11.7
21.27	15.2	42.17	33.2	33.03	1	1	1	6.53	2	2	10.83	8.4	12.78	11.7
21.7	15.6	32.97	42	24.63	2	2	2	12.23	2	2	8.54	7.8	8.94	8.8
20.17	14.9	30.46	44.3	23.41	2	2	2	7.21	2	2	9.77	7.3	10.95	12.4
			36.473											

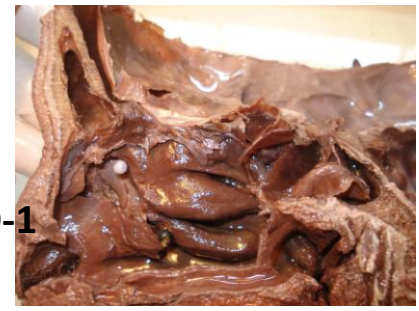
NLD-MSO	CTNLD-MSO	NLD-ANS	NLDo-NF	CTNLDo-NF	NLDo-ITa	CTNLDo-ITa
4.23	3.4	33.04	14.86	12	16	12.7
3.18	4.2	28.97	12.41	10	13.46	10.8
4.5	4.4	16.13	12.13	12.2	10.44	9.8
4.11	3	24.1	11.16	13.1	16.78	12.6
4.43	3.5	30.88	16.97	14.8	17.55	12.6
3	4.8	32.6	18.88	16	20.08	13.9
2.26	3.5	29.56	14.78	13	18.41	16.3
5.23	3.5	23.57	19.55	18	18.27	16.6
3.27	4	23	8.56	9.1	13.84	15
4	4.9	26.67	10.31	10.4	15.87	12.5
2	3.5	20.26	14.66	12	11.06	12.5
2	2.8	21.31	15.59	13.8	10.61	11.7
3.69	5.6	22.52	16.33	16	15.93	11.5
4.73	5	27.14	16.26	14.9	14.81	10.8
5	5	25.79	9.2	8.8	12.93	13.6
5.3	5	25.85	10.94	12.8	11.5	12
4.83	4.5	28.45	15.49	12.1	15.17	11.8
4.8	5.4	23.78	14.94	11.8	15.95	12.4
5.51	5.6	21.68	15.63	18.9	13.22	12.7
4.76	5.9	20.17	13.36	15.4	12.89	10.7

PROFORMA

1. Maxillary line:_____clear,_____not clear
2. Length of maxillary line- from axilla to inferior turbinate
3. Distance from
    a) Anterior nasal spine to most anterior point of middle turbinate
    b) Anterior nasal spine to axilla of middle turbinate
    c) Anterior nasal spine to M point (mid point of maxillary line)
    d) Maxillary sinus ostium to M point
4. Relation of lacrimomaxillary suture line to maxillary line(anterior/posterior/over)
5. Thickness of lacrimal bone
6. After removal of lacrimal bone: lacrimal sac seen
    - (more than half ___/less than half___/ not seen___)
7. Distance between
    a) Posterior edge of lacrimal sac and axilla of middle turbinate
    b) Anterior edge of lacrimal sac and axilla of middle turbinate
    c) Posterior edge of lacrimal sac to anterior most point of middle turbinate
    d) Posterior edge of lacrimal sac and maxillary sinus ostium
    e) Posterior edge of lacrimal sac and ethmoidal bullae
8. Superior end of sac (at / below/ above axilla)
9. Inferior edge of lacrimal sac and inferior turbinate
10. Anteroposterior diameter of lacrimal sac
11. Length of lacrimal sac
12. Distance between
    a) Fornix of lacrimal sac and axilla of middle turbinate
    b) Fornix to ostium
    c) Anterior nasal spine and fornix of lacrimal sac
    d) Anterior nasal spine and inferior edge of lacrimal sac

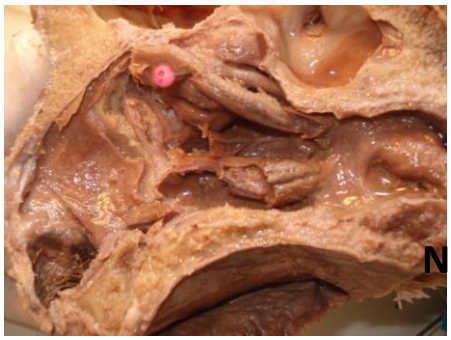
13. The relationship between the lacrimal sac and the axilla of the middle nasal concha.
14. The relation between the lacrimal sac and the maxillary line.
15. Posterior edge of nasolacrimal duct and ethmoidal bullae
16. Relation of anterior point of middle turbinate to nasolacrimal duct:(at/anterior/posterior)
17. Nearest distance between genu and duct
18. Length of the nasolacrimal duct (from the transition area between the sac and duct up to the intranasal orifice)
19. Nearest distance from the
    a) Nasolacrimal duct to the maxillary sinus ostium
    b) The Nasolacrimal duct to the anterior nasal spine
    c) Intranasal orifice of the nasolacrimal duct to the nasal floor
    d) Intranasal orifice of the nasolacrimal duct to anterior attachment of the inferior turbinate.





NLD-1

NLD-2



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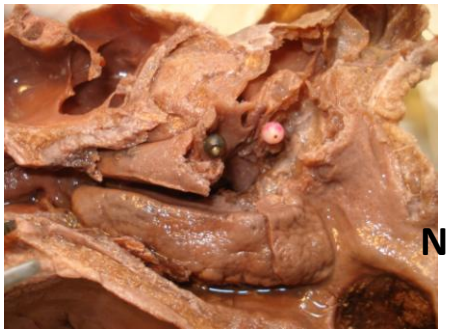
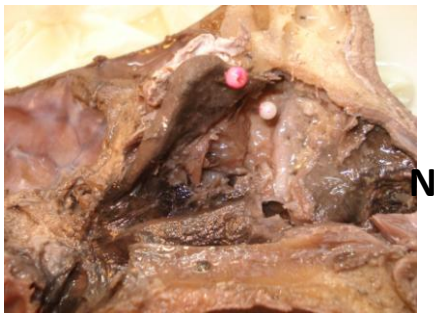
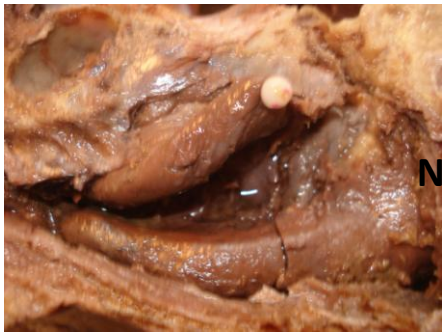


NLD-4

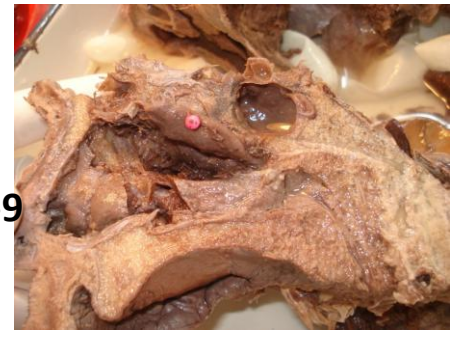



NLD-5

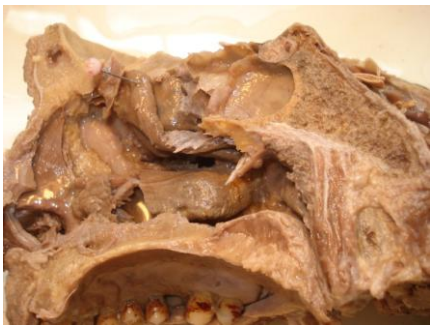



NLD-6

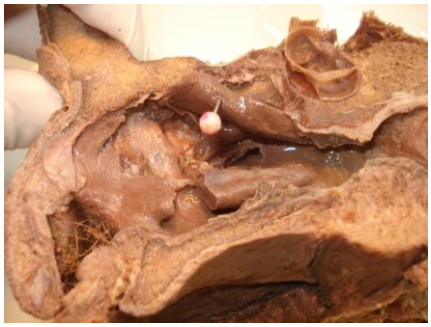

NLD-7

NLD-9



NLD 10



NLD 11

POST DISSECTED SPECIMEN –NLD-1 TO NLD-11(NLD 8 was not included in study)