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ORIGINAL ARTICLE

Anatomical Variation of Lacrimal Sac Fossa and Bony Nasolacrimal Duct among Adult Egyptians: Dry Bone and Radiological Study

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ABSTRACT

Background: Successful lacrimal surgery begins with understanding the anatomy of the lacrimal drainage system. Detailed knowledge of the orientation of the bony lacrimal passages is a key feature for success of lacrimal probing and intubation. The present study was assigned to demonstrate the anatomy of the lacrimal drainage system and its variants among adult Egyptians. **Material and methods**: The study included 44 dry skulls and 83 multidetector computed tomography (MDCT) images of adults of both sexes. The anterior and posterior lacrimal crests were examined in dry bones. The length, width of the upper, middle and lower thirds of lacrimal sac fossa (LSF) were measured using the digital Vernier caliper. Radiological CT images were examined for anteroposterior and transverse diameters of the entrance, narrowest point and exit of nasolacrimal duct (NLD). The length of NLD and the angle between the longitudinal axis of the NLD and floor of the nose were measured. **Results:** The LSF was formed by the frontal process of maxilla and lacrimal bone at different proportions. The width of the middle and lower thirds of LSF were significantly greater in males than females. Radiological CT images showed that the anteroposterior and transverse diameters of the entrance of the NLD were significantly greater in females than males below 40 years. **Conclusion:** Sex and age of the patient should be considered while selecting the optimal NLD stent for patient with NLD obstruction. The precise dimensions of NLD can reduce the risk of injury during the transnasal operations.

Key words: Lacrimal sac fossa, Nasolacrimal duct, Length, Diameter, Aeration

INTRODUCTION

Epiphora (excess tearing) due to nasolacrimal duct (NLD) obstruction is a common ophthalmological problem [1]. Obstruction of the lacrimal drainage system may be congenital or acquired. The causes of acquired obstruction are classified into primary and secondary causes. The latter may be caused by trauma, infection, inflammatory disease, or malignancy [2].

Primary NLD obstruction is an idiopathic condition. Despite the etiology is unknown, anatomical factors have been proposed [3, 4]. This condition has been associated with variations of morphometric characteristics of the fossa for lacrimal sac and the bony NLD. These variations are determined by the patient's age, sex, and race [1, 5]. It has been suggested that racial and sex differences in facial skull dimensions may explain narrower NLD and therefore differences in the incidence of NLD obstruction [6].

The diameter of the NLD alone does not fully explain or predict the occurrence of primary acquired NLD obstruction [4]. Air within the nasolacrimal drainage system is often regarded as a common normal variant [7]. The presence or lack of aeration may help identify individuals at risk for developing nasolacrimal system dysfunction. It was reported that NLD system aeration shows sex and age differences [2].

There is little knowledge about racial variations of the lacrimal sac fossa (LSF) anatomy and its influence on achieving successful surgical outcomes. For example, performing dacryocystorhinostomy (DCR) surgery is postulated to be more challenging in black Africans due to their flat nasal bridge [8]. Therefore, anatomical understanding of the LSF is very important for lacrimal drainage after surgeries

such as DCR and conjunctivo-dacryocystorhinostomy [9].

Computed tomography (CT) imaging is an important tool in understanding physiological and pathological changes within the lacrimal drainage system. It is the preferred lacrimal imaging modality when diagnosis of epiphora is uncertain. Moreover, it is a reliable and repeatable modality to assess nasolacrimal system aeration and NLD parameters [2]. It is possible to evaluate NLD with thin slices in different planes by using multidetector computed tomography (MDCT) [10].

The present study was assigned to analyze the morphologic characteristic of the LSF regarding sex using dry skulls of adult Egyptians with different ages. It also aimed to provide some morphometric data concerning the NLD and its variations and to identify aerations of the NLD regarding to age and sex using MDCT images.

METHODS

Material:

I-Dry bones:

Forty four fully ossified skulls of both sexes were included in the study. Sex determination was done according to **Devi [11].** After exclusion of orbits with fractured lacrimal fossae, the total number of the studied lacrimal sac fossae was 80 (41 fossae in males and 39 fossae in females). The bones were obtained from the Anatomy and Embryology Department, Faculty of Medicine, Cairo University. Skulls with fracture in the orbit, incomplete ossification and bones with any gross pathological abnormalities were excluded from the study.

II. Radiological images:

The study also included 83 MDCT radiographs for Egyptian patients (39 males and 44 females, age ranged from 18 to 80 years). A total number of 160 NLDs were evaluated (77 ducts in males and 83 ducts in females). The images were obtained from the Radiology Department, Faculty of Medicine, Cairo University over a period of six months (January 2019 - June 2019). The patients underwent MDCT angiography for reasons other than evaluation of lacrimal drainage system (chronic sinusitis, headache, and intracranial lesions).

The CT images were divided into two groups according to age; Group A: consisted of 39 radiological images belonging to patients below the age of 40 (25 males and 14 females). Group B: consisted of 44 CT images for patients above the age of 40 (14 males and 30 females).

Inclusion criteria: Adult male and female

Exclusion criteria:

1- Syndromic craniofacial anomalies

2- History of any disease, neoplasm, or fracture in the nasolacrimal canal region.

3- Patients with history of any facial bone operations

Methods:

I-Dry bone study:

A) Qualitative study:

The lacrimal sac fossae were examined for the shape and variable contributions made by the frontal process of the maxilla and the lacrimal bone. They were classified as follows: Fossae made by lacrimal bone only, fossae made by fontal process of maxilla only and fossae made by both lacrimal bone and fontal process of maxilla. The lacrimomaxillary suture was evaluated. The anterior lacrimal crest (ALC) and posterior lacrimal crest (PLC) were examined for the sharpness of the crests and the forming bone. The presence of lacrimal hammulus and lacrimal tubercle was evaluated [12].

B) Quantitative study:

The following parameters were measured using the digital Vernier caliper and recorded [13]; Length (L) of the lacrimal fossa (in mm): It was measured from the point of meeting of ALC and PLC to the entrance of NLD (Fig.1a, b). Width (W1) of the upper third of the lacrimal fossa (in mm): It was measured from posterior surface of ALC to anterior surface of PLC at the middle of upper third of LSF (Fig. 1c, d). Width (W2) of the middle third of the lacrimal fossa (in mm): It was measured from posterior surface of ALC to anterior surface of PLC at the middle of middle third of LSF (Fig. 1c, d). Width (W3) of the lower third of the lacrimal fossa (in mm): It was measured from posterior surface of ALC to anterior surface of PLC at the middle of lower third of LSF (Fig. 1c, d).

III. Radiological study:

MDCT was performed using a 32-row MDCT system (Siemens) with Contiguous axial 2-mm–thick sections parallel to the infraorbitomeatal line. Coronal as well as sagittal scans perpendicular to this plane were acquired with a field of view of 180mm, matrix size of 512×512 and a reconstruction kernel for bone at Radiology Department, Faculty of Medicine, Cairo University.

Scanning method and data processing:

Multiplanar reconstruction of the CT images was done and the anatomical features of the NLD were studied in the coronal, sagittal, and axial planes. The long and short diameters of the NLD were

measured along its cross-section. The free and open-source software (the RadiAnt DICOM viewer) was used for the segmentation of the NLD and three-dimensional visualization of the superior (entrance), inferior (exit) openings and narrowest point of the NLD [14]. To ensure the minimum diameter had been measured, several measurements were taken in different axes and the least one was recorded. The frames above and below were also measured to confirm the narrowest point of the canal had been measured [3].

Each radiological image was evaluated for:

1. **The antroposterior diameter (APD) and transverse diameter (TD) of NLD (in mm):** They were measured at three levels; Proximal end (entrance): The superior opening was located using the medial orbital corner [14] (Fig. 2a). Narrowest point: to ensure that the minimum diameter had been determined accurately, several measurements were taken at different levels and the least one was recorded [15] (Fig. 2b). Distal end (Exit): The inferior opening of the NLD was located using the nostril and the midsagittal line [14] (Fig. 2c).
2. **The length (L) of NLD (in mm):**
   It was measured as the long axis extending from the proximal end of the duct at the junction with the lacrimal sac to the distal end at the level of inferior meatus in sagittal plane [10] (Fig. 2d).
3. **The Angle:**
   The angle between the longitudinal axis of the NLD and floor of the nose in the sagittal view was measured [16] (Fig. 2e).
4. **The aeration of the NLD:**
   The presence of air within the NLD was examined in axial and coronal sections. The NLD were further classified as fully aerated, partially or non-aerated. The fully aerated duct was defined as a continuous column of air filling the whole NLD [2]. In partially aerated NLD, part of the lumen is opaque. The term "non aerated" NLD was used if the duct was completely opaque [17].

Study population and sample size:

The sample size was calculated using online calculator Statulator Beta using confidence level 95%, expected standard deviation 0.9 and margin of error 0.15. The required sample was found to be 71 radiological images (142 nasolacrimal ducts). In the present study, 80 radiological images (160 nasolacrimal ducts) were included. The same method was used to calculate sample size of the dry bone.

Statistical analysis:

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 25 (IBM Corp., Armonk, NY, USA). Data was described using mean, standard deviation, minimum and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Kruskal-Wallis, Mann-Whitney and chi square tests. P-values less than 0.05 were considered as statistically significant.

RESULTS

I-Dry bone results:

A. Qualitative results:

Shape of the lacrimal sac fossa:

The lacrimal sac fossa (LSF) was oval in shape in 100% of cases.

- **Bone contribution in LSF (Chart 1):**
  The LSF was formed by the frontal process of maxilla and lacrimal bone in an equal proportion in 45% of cases (36 fossae) and the lacrimomaxillary suture (LMS) was observed in the middle of the fossa (Fig. 3a). It was formed mainly by frontal process of maxilla in 32.5% of cases (26 fossae) and the LMS was observed in the posterior part of the fossa (Figs.3b, c). The LSF was formed of lacrimal bone mainly in 15% of cases (12 fossae) and the LMS was detected in the anterior part of the fossa (Figs. 3d, e). The LSF was formed completely by the frontal process of maxilla in 7.5% of cases (6 fossae). In those fossae, the LMS was seen behind the PLC (Fig. 3f)
- **Anterior lacrimal crest (Chart 2):**
  Anterior lacrimal crest (ALC) was well defined along its whole length in 88.75% of cases (71 crests) (Figs.3a, f). The lower part of the crest was well defined in 7.5% of cases (6 crests) (Fig.3b). Only one crest (1.25%) was well defined with a notch on its lower end (Fig.3c) and two crests (2.5%) were ill defined (Fig.3e). The ALC was formed by frontal process of maxilla in 100 % of cases (80 crests).
- **Posterior lacrimal crest (Chart 3):**
  Posterior lacrimal crest (PCL) was sharp in 75 % of cases (60 crests) (Fig.3c). It was sharp at the lower part in 12.5% of cases (10 crests) (Fig. 3d) and blunt in 10% of cases (8 crests) (Fig.3b). One crest (1.25%) was sharp with projection at middle (Fig.3a) and one crest (1.25%) was flat (Fig.3e). The PLC was formed by lacrimal bone in 92.5% of cases (74 crests) and was formed by maxilla 7.5% of cases (6 crests).
- **The presence of lacrimal hammulus and lacrimal tubercle:**
  The lacrimal hamulus was observed in the lower part of PLC in 46.3% of cases (37 hamulus) (Figs.3a,

d) and the lacrimal tubercle was seen at the lower part of ALC in 23.8% of cases (19 tubercles) (Figs.3a, c)

B. Quantitative results (Table 1):

The difference in the mean length of LSF between males and females was statistically non-significant (p=0.123). The difference in the mean width of LSF between males and females was statistically non-significant in the upper third (p=0.067), however, it was significant in the middle (p=0.029) and lower third (p<0.001) of LSF.

II. Radiological results:

1. The anteroposterior and transverse diameters of NLD:

A- Proximal end (entrance):

-Anteroposterior diameter (APD):

In males, there was non-significant difference in the mean APD of the entrance of NLD below and above 40 years (p=0.460). In females, there was significant decrease in the mean APD of the entrance of NLD above the age of 40 years compared to the age below 40 years (p< 0.001) (Table 2).

Considering sex difference, the mean APD of the entrance of NLD was significantly higher in males compared to females below 40 years (p< 0.001), while above 40 years, the difference between both sexes was found to be statistically non-significant (p=0.393) (Table 3).

-Transverse diameter (TD):

In males, the mean TD of the entrance of NLD showed non-significant difference above and below 40 years (p=0.096). In females, there was significant decrease in the mean TD above the age of 40 years compared to below 40 years (p< 0.001) (Table 2). When comparing males to females, the mean TD of the entrance of NLD in males was significantly less than females below the age of 40 years (p <0.001). The difference between both sexes was found to be statistically non-significant above 40 years (p= 0.886) (Table 3).

B- The narrowest point:

-Anteroposterior diameter (APD):

There was statistical non-significant difference in the mean APD of narrowest point of NLD between males below and above 40 years (p=0.387). Regarding females, the difference between the two age groups was found to be statistically non-significant (p= 0.058) (Table 2). When comparing males and females, there was non-significant differences in the mean APD of narrowest point of NLD between both sexes below 40 years (p= 0.138) and above 40 years (p= 0.391) (Table 3).

-Transverse diameter (TD):

In males, there was non-significant difference in mean APD of narrowest point below and above 40 years (p= 0.053). In females, there was statistically significant decrease in the mean TD of the narrowest point of NLD above 40 years when compared to females below 40 years (p= 0.001) (Table 2). When comparing both sexes, the mean TD of the narrowest point of NLD was statistically non-significant between males and females below 40 years (p=0.065) and above 40 years, (p= 0.718) (Table 3).

C- The exit:

-Anteroposterior diameter (APD):

In males, there was non-significant difference in the mean APD of the exit of NLD below and above 40 years (p= 0.171).In females, there was statistically significant decrease in the mean APD of exit of NLD between the two age groups (p= 0.004) (Table 2). Regarding sex, the difference in the mean APD of the exit of NLD between males and females was non-significant below 40 years (p=0.168) and above 40 years (p= 0.925) (Table 3).

-Transverse diameter (TD):

There was non-significant difference in the mean TD of the exit of NLD in males below and above 40 years (p= 0.673). In females, there was a statistically significant decrease in the mean TD of the exit of NLD above 40 years compared to females below 40 years (p= 0.029) (Table 2). When comparing males and females, the difference in the mean TD of the exit of NLD was found to be statistically non-significant below 40 years (p= 0.057) and above 40 years (p= 0.278) (Table 3).

2. The length of NLD:

In males, the difference in mean length of NLD between the two age groups was found to be statistically non-significant (p= 0.587). In females, there was significant decrease in the mean length of NLD above 40 years compared females below 40 (p< 0.001) (Table 2). Regarding sex difference, there was non-significant difference in the mean length of NLD between males and females below the age of 40 (p=0.1) and above the age of 40 years (p= 0.215) (Table 3).

3. The Angle:

In males, the difference in mean angle between NLD and the floor of the nose below the age of 40 years and above the age of 40 was found to be statistically non-significant (p= 0.401).In females, the difference was found to be statistically non-significant between the two age groups (p=0.146) (Table 2).When comparing males and females, the difference in mean angle between NLD and the floor of the nose was found to be statistically non-

significant below the age of 40 years (p= 0.313) and above the age of 40 years (p=0.815) (Table 3).

4. Aeration of NLD:

In males, the NLD was totally aerated in 30% of cases below 40 years and 29.6% above 40 years (Figs. 4 a,b). The difference between the two age groups was found to be statistically non-significant (p= 0.973) (Table 4). In females below 40 years, the NLD was totally aerated in 14.3% of cases, while above 40 years; it was totally aerated in 21.8 % of cases (Fig. 4c). The difference between the two age groups was found to be statistically non-significant (p= 0.411) (Table 4).

The NLD was partially aerated in 46% of cases in males below 40 years and 25.9% above 40 years (Fig. 4a). The difference between the two age groups was found to be statistically non-significant (p= 0.085) (Table 4). In females, the NLD was partially aerated in 85.6% of cases below 40 years and 36.4% of cases above 40 years (Fig. 4d). There was statistically significant decrease in the prevalence of partially aerated NLD in females above 40 years when compared to females below 40 years (p<0.001) (Table 4).

The NLD was non-aerated in 24% of cases in males below 40 years and 44.4% above 40 years (Figs. 4b, e). The difference between the two age groups was found to be statistically non-significant (p= 0.065) (Table 4). In females, non-aerated NLD was not detected below the age of 40 years, while above 40 years, it was observed in 41.8% of cases (Fig. 4f). The difference in prevalence of non-aerated NLD between the two age groups was found to be statistically significant (p<0.001) (Table 4).

When comparing males and females, the difference in the prevalence of totally aerated NLD between both sexes was found to be statistically non-significant below the age of 40 years (p= 0.121) and above the age of 40 years (p= 0.439) (Table 5).

There was significant increase in the prevalence of partially aerated NLD in females as compared to males below 40 years (p=0.001). Above 40 years, the difference in the prevalence of partially aerated NLD between both sexes was found to be statistically non-significant (p= 0.345) (Table 5).

The NLD was non-aerated in 24% of cases in males below 40 years, while in females below 40 no cases were found. The difference between sexes was statistically significant (p= 0.003). Above 40 years, there was statistical non-significant difference in the prevalence of non-aerated NLD between both sexes (p= 0.821) (Table 5).

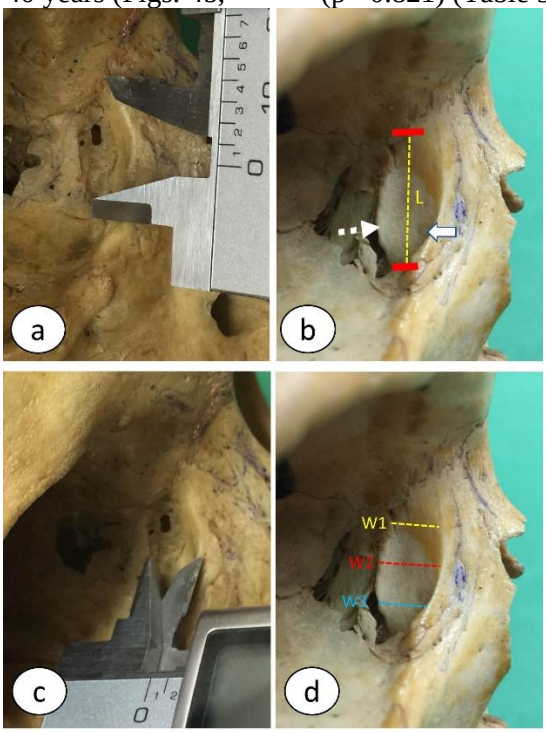

Figure (1): Photographs of the right bony orbits showing the lacrimal sac fossae. a, b) The length (L) of the LSF is measured from the point of meeting ALC (arrow) and PLC (dotted arrow) to the entrance of NLD (lower red line) using digital vernier caliber. **c. d)** The width of the upper third (W1), middle third (W2) and lower third (W3) of the LSF is measured by digital vernier caliber.

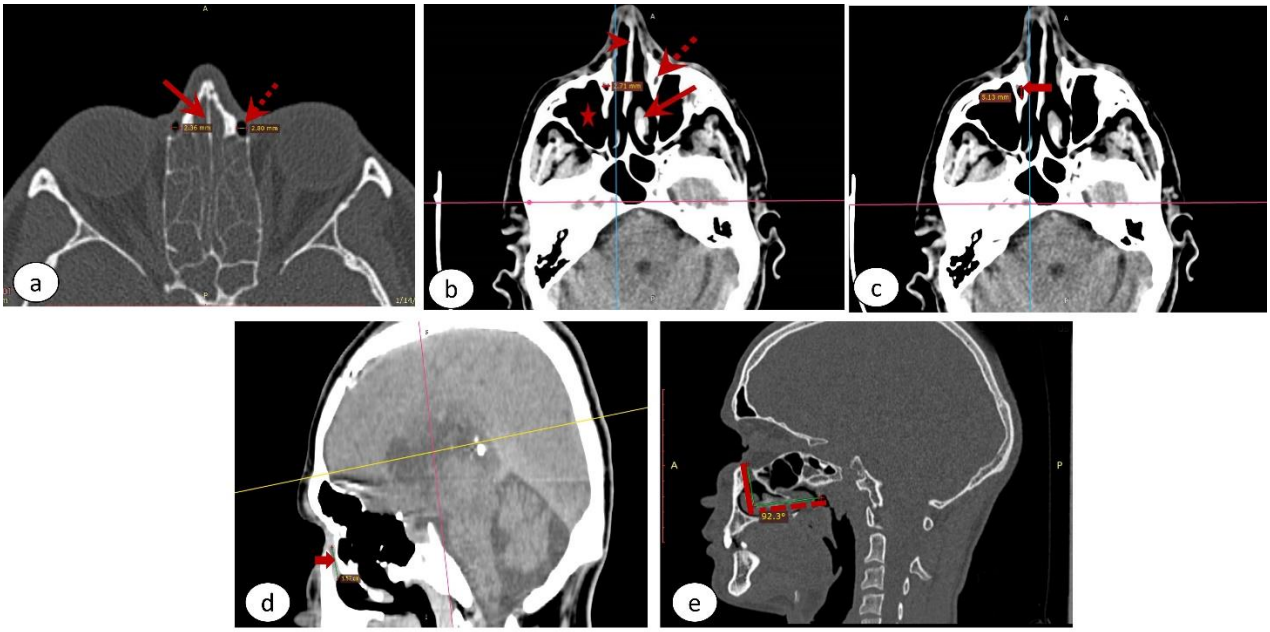

Figure (2): Axial (a, b, c) and sagittal (d, e) CT images showing: a) The transverse diameter of the entrance of the NLD. The NLD (dotted arrow) and nasal septum (arrow) are demonstrated. **b)** The transverse diameter of the narrowest point of the NLD. The NLD (dotted arrow), nasal septum (arrowhead), inferior nasal concha (arrow) and maxillary air sinus (asterisk) are illustrated. **c)** Anteroposterior diameter of the NLD at level of exit (arrow). **d)** Length of NLD (arrow). **e)** The angle between longitudinal axis of the NLD (line) and the floor of the nose (dotted line).

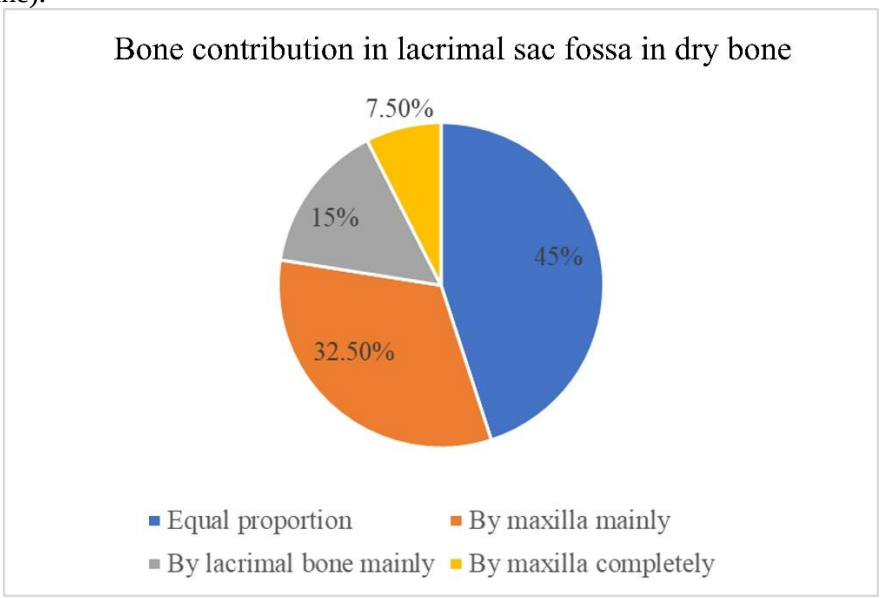

Chart (1): Pie chart showing bone contribution in lacrimal sac fossa in dry bone

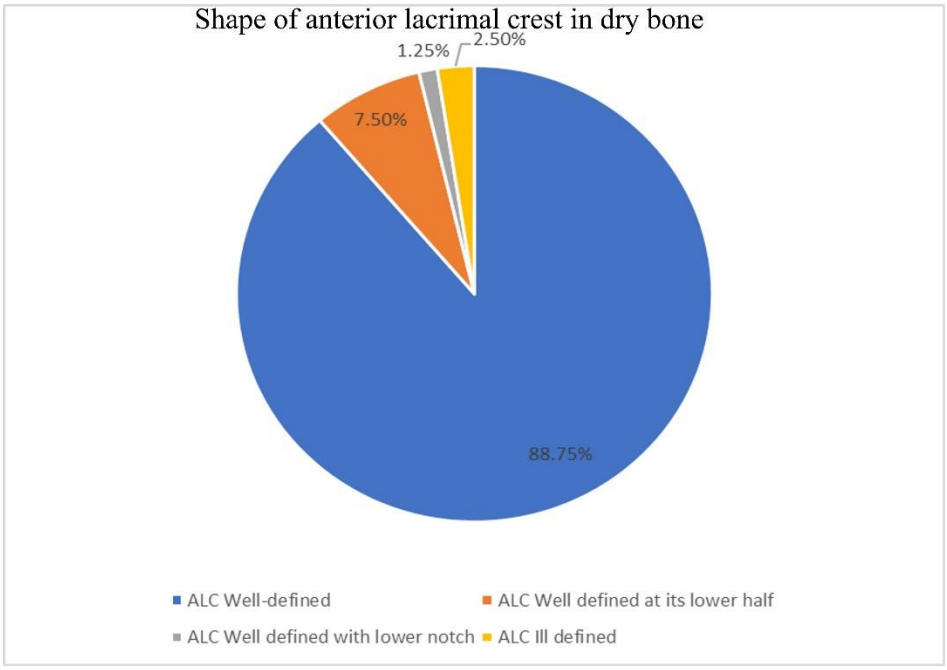

Chart (2): Pie chart showing percentage of ALC shape categories in dry bone

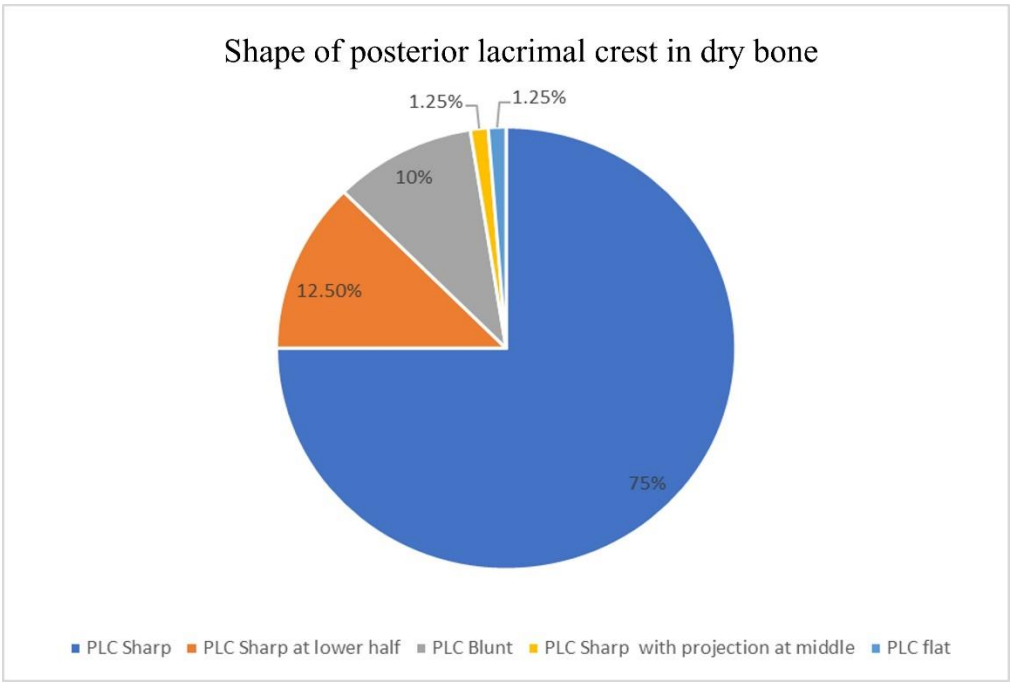

Chart (3): Pie chart showing percentage of PLC shape categories in dry bone

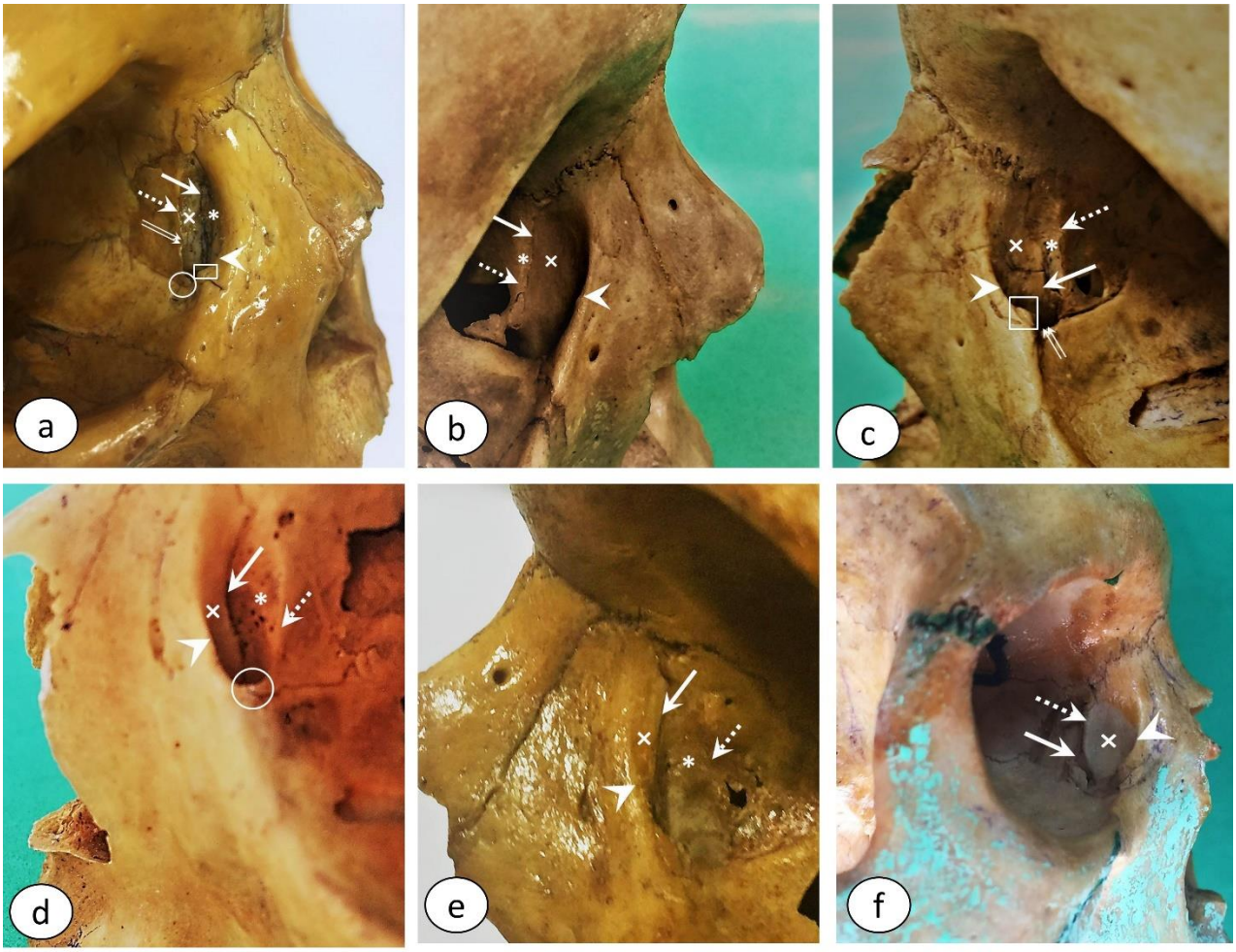

Figure (3): Photographs of the right (a, b, f) and left (c, d, e) bony orbits showing the lacrimal sac fossae. a) The LSF is formed by frontal process of maxilla (*) and lacrimal bone (×) in an equal proportion (1:1). The LMS (arrow) lies at the middle of the fossa. The ALC (arrowhead) is well defined along its whole length and formed by frontal process of maxilla. The PLC (dotted arrow) is sharp with projection at the middle (double arrows) and formed by lacrimal bone. The lacrimal tubercle (rectangle) is demonstrated at the lower end of the ALC and the lacrimal hamulus (circle) is illustrated at the lower end of PLC. **b)** The LSF is formed by frontal process of maxilla (×) and lacrimal bone (*) in proportion of 5:1 (formed mainly by maxilla). The LMS (arrow) lies at the posterior part of the fossa. The ALC (arrowhead) is well defined at its lower end and formed by frontal process of maxilla. The PLC (dotted arrow) is blunt and formed by lacrimal bone. **c)** The LSF is formed by frontal process of maxilla (×) and lacrimal bone (*) in proportion of 2:1 (formed mainly by maxilla). The LMS (arrow) lies at the posterior part of the fossa. The ALC (arrowhead) is well defined and formed by frontal process of maxilla. The PLC (dotted arrow) is sharp and formed by lacrimal bone. A notch (double arrows) and lacrimal tubercle (rectangle) are demonstrated at the lower end of ALC. **d)** The LSF is formed by frontal process of maxilla (×) and lacrimal bone (*) in proportion of 1:2 (formed mainly by lacrimal bone). The LMS (arrow) is seen at the anterior part of the fossa. The ALC (arrowhead) is well defined along its whole length and formed by frontal process of maxilla. The PLC (dotted arrow) is sharp at its lower half and formed by lacrimal bone. The lacrimal hamulus (circle) is demonstrated at lower end of PLC. **e)** The LSF is formed by frontal process of maxilla (×) and lacrimal bone (*) in proportion of 1:3 (formed mainly by lacrimal bone). The LMS (arrow) is seen at the anterior part of the fossa. The ALC (arrowhead) is ill defined and formed by frontal process of maxilla. The PLC (dotted arrow) is flat and formed by lacrimal bone. **f)** The LSF is formed totally by frontal process of maxilla (×). The ALC (arrowhead) is well defined along its whole length and PLC (dotted arrow) is sharp. They are formed by maxillary bone. The LMS (arrow) is seen behind the PLC

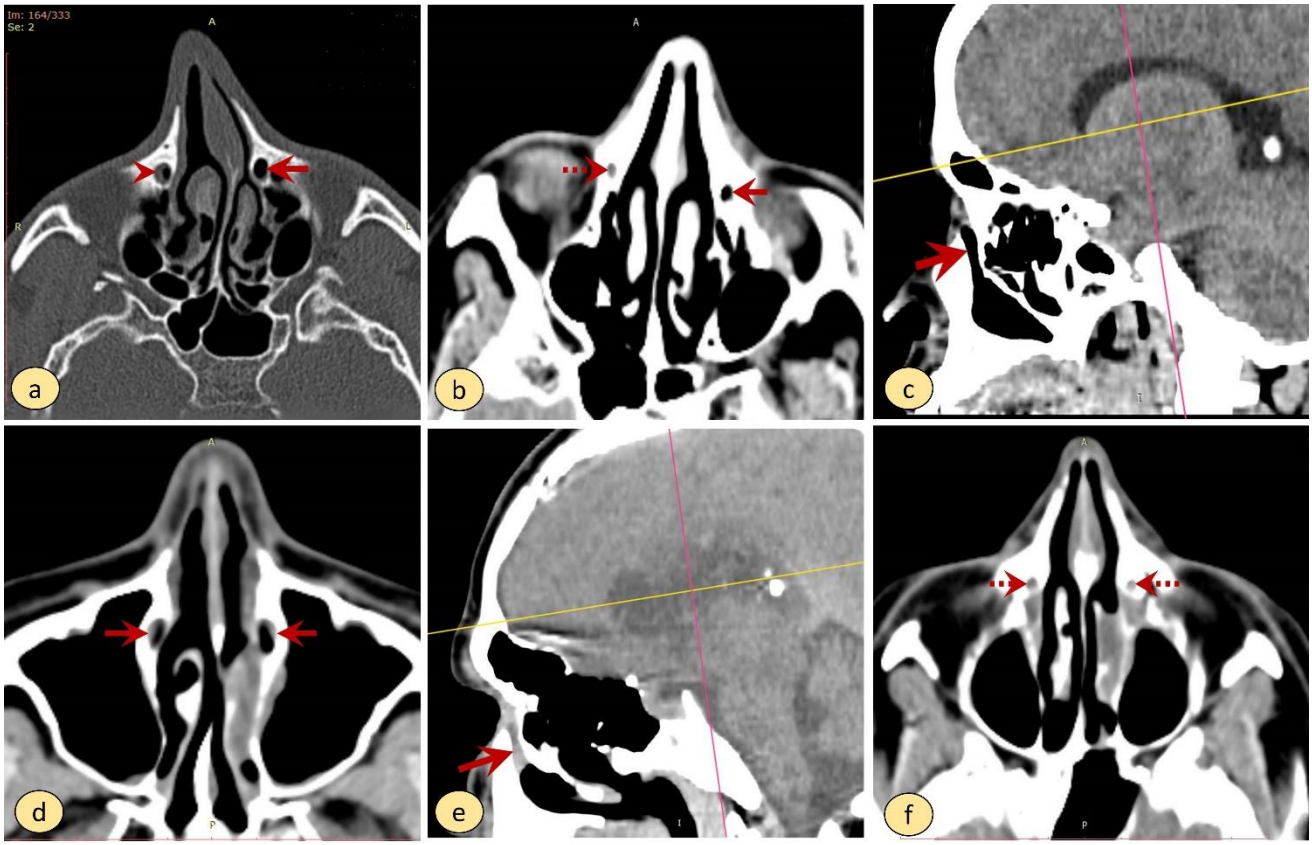

Figure (4): Axial (a, b, d, f) and sagittal (c, e) CT images showing: a) Partially aerated NLD on the right side (arrowhead) and totally aerated NLD on the left side (arrow) (male patient aged 22 years). **b)** Non aerated NLD on the right side (dotted arrow) and totally aerated NLD on the left side (arrow) (male patient aged 31 years). **c)** Totally aerated NLD (arrow) (female patient aged 29 years). **d)** Partially aerated NLD on both sides (arrows) (female patient aged 43 years). **e)** Non aerated NLD (arrow) (male patient aged 31 years) **f)** Non aerated NLD on both sides (dotted arrows) (female patient aged 43 years).

DISCUSSION

Understanding the anatomy of the LSF and NLD and having the ability to locate their openings are necessary for NLD obstruction surgery [14]. Comprehensive prediction of anatomical variation is crucial for surgical success. Therefore, it is important to be aware of lacrimal bone characteristics in patients of different ethnic groups [15].

In the current study on dry bone, LSF was oval in shape in 100% of orbits, which disagreed from data provided by **Bisaria et al. [18]**, who found that the LSF was oval in 75% of orbits, irregular in 8.3 % and not defined in16.7 % of orbits.

In the present work, the LSF was formed by lacrimal bone and frontal process of maxilla in an equal proportion in 45% of cases. This finding agreed with **Agarwal and Kumar[12],**who mentioned that the contribution by lacrimal bone and maxilla was equal in 46.56% on the right side and 46.06% on the left side. In contrary, **Bisariaet al. [18]** reported that the LSF was formed equally by lacrimal bone and maxilla in most of cases (79.2 %).

In the current study, ALC was well defined in 88.75% of observations. This was in accordance with **Bisaria et al.[18],**who reported that the ALC was well defined in 80% of orbits. **Agarwal and Kumar [12]** also mentioned comparable incidences (89.42% well defined ALC on the right side and 90.45% on the left side).Anterior lacrimal crest was ill defined in two crests only in this work. This finding wasn´t observed by **Agarwal and Kumar [12]** in their study on Indians.

Regarding PLC, it was sharp in most of cases(75 %) in the present study. This was in accordance with **Bisaria et al. [18]** (80%) and **Agarwal and Kumar[12]**(79.37%on the right side and 78.66% on the left side). The PLC was blunt in 8% of cases in this work. A higher incidence (11.11% on the right side and 11.24% on the left side) was reported by**Agarwal and Kumar [12]**. The PLC was sharp

with a projection at its middle in one crest in the current study. Few cases were also detected by **Agarwal and Kumar [12]**(Four PLC; two on the right and two on the left side). These authors reported sharp PLC in upper half in four crests, which wasn´t found in the current study.

In the current work, the meanlength of LSF was 14.20 ± 1.6 mm in malesand 13.94±1.51mm in females.This data agreed with **Fayet et al.[19],** who worked on European population andreported that the mean length of LSF was 12.06±1.93mm by using CT scan. In contrary, **Costa and Ramanathan[20]**studied the length of LSF regarding the side in Indian population andreported smaller measurements (10.5 ±1.048mm on the right side and 10.57±1.13 mm on the left side). **Yong et al. [15]**found that its mean length was 17.14 mm in Malysian population. This obvious difference could be explained by variation between the different ethnic groups.

In the present study, non-significant difference was found in the mean length of and upper width of LSF between males and females, however, the mean middle and lower widths were significantly higher in males compared to females. In the reviewed literature, sex difference in these parameters were not assessed.

The NLD is involved in many surgical procedures such as artificial NLD implantation, pipe silicone, retrograde catheterization, and stenting. The main challenge of the procedures is the difference in size of NLD in both sexes and different ages**,** which casts difficulty in selecting a suitable artificial duct [14]. Therefore, detailed information about NLD has become essential although the description regarding the anatomy of the duct is obscure in the textbooks and medical literatures [21].

In the present study, CT scans showed that the diameters and length of NLD varied according to sex and age. There was a decrease in the mean APD and TD of the entrance of the NLD above 40 years compared to below 40 years in both males and females. This decrease was statistically non-significant in males; however, it was significant in females. In the available literature, no previous studies were done concerning APD of the entrance of NLD. **Bulbul et al. [10]** demonstrated that the mean TD of the entrance of NLD was 4.4±0.9 mm in Korean population, which is greater than the values reported in the current study, which might be attribute to racial factor.

In the current work, there was a non-significant difference in the mean APD of the narrowest point of NLD above 40 years compared to below 40 years in both males and females. **Yong et al.[15]** found that mean APD of narrowest point of NLD was 3.82mm (on the right side) and 3.78 (on the left side) in Southeast Asians and 3.54 mm (on the right side) and 3.81 mm (on the left side) in South Asians and Caucasians, which is almost comparable with the data provided in the present study. On the other hand, a study carried out by **McCormick and Sloan [22]** showed that the narrowest NLD diameter was wider in the Pacific race (4.1 mm) as compared to the current work. **Yong et al. [15]** reported that NLD diameter varies between different races. For example, people with narrower faces such as patients with Caucasianoid features have significantly narrower NLD and may be predisposed to NLD obstruction. The authors further added that clinical study of the incidence of NLD obstruction in different races will be necessary to prove this theory.

Regarding the mean TD of the narrowest point of the NLD in this work, it was shorter above 40 years compared to below 40 years in both males and females. This difference was non-significant in males; however, it was significant in females. In agreement to these findings, **Janssen et al.[23]** and **Shigeta [1]**reported that the NLD diameter is narrower in women and in patients with NLD obstruction.

In the present study, there was a significant decrease in the mean APD and TD of the exit of the NLD in females above 40 years compared to females below 40 years, while in males the difference between the two age groups was statistically non-significant. Therefore**, Zhang et al. [14]** suggested that the artificial NLD and should be selected carefully in females to avoid duct sliding and mucosal injury. **Cowen and Hurwitz [24]** reported that the mean APD of the exit of NLD was 4-8mm and the TD was 3-5mm, but they didn´t study age and sex differences.

Regarding sex difference in the APD and TD of the entrance, the narrowest point and exit of the NLD, the mean APD and TD of the entrance of NLD was significantly greater in females compared to males below the age of 40 years. The difference between males and females was statistically non-significant in the rest of parameters in the present study. In agreement to the current work, **Janssen et al.[23]**reported that the difference in the TD of the narrowest point of NLD between males (3.70mm) and females (3.35mm) was statistically non-significant. In contrast to the present results, **Shigeta [1]**carried out a study in Japan and reported that the

mean APD and TD of NLD at the level of the infraorbital margin was significantly greater in males (5.8 ±1.2 mm and 5.1 ±1.1 mm respectively) than in females (5.3 ±1.2 mm and 4.8 ±1.1 mm respectively). Regarding length of the NLD in this study, there was a non-significant increase in the mean length of NLD in males above 40 years compared to males below 40 years, which was in accordance with the data provided by **Zhang et al. [14].** In females, there was a significant decrease in the mean length of the NLD above 40 years compared to below 40 years in the current work. In contrast, **Zhang et al. [14]**reported that the NLD was significanlty longer in elderly females (above 40 years) as compared to young females in China.

In the current work, age and sex differences in the mean angle between NLD and the floor of the nose were statistically non-significant. The mean angle provided by **Shigeta [1]**(78.3° in Japanese population) and **Bulbul et al.[10]** (74.5° in Korean population) were smaller than the values of the current work, which might be attributed to.It was reported that not just the diameter but the angle of NLD may also play an important role in the occurrence of NLD obstruction**[15].**

Most of studies regarding NLD have focused on the diameter, area, nasolacrimal volume, or duct angle in relation to the nasal floor. Few studies discussed the presence or absence of air on nasolacrimal imaging [7]. The significance of this finding is not well illustrated and is historically regarded as a normal variation. Therefore, there is lack of data concerning factors influencing the presence of air in the NLD on CT imaging [25].

In the current study, the prevalence of fully aerated NLD showed a non-significant difference between males and females, below and above 40 years. Regarding partially aerated NLD, statistically significant difference was found in the between males (46.0%) and females (85.7%) below 40 years. Moreover, there was a statistically significant difference in the prevalence of non-aerated NLD between males (24.0%) and females (0%) below 40 years. On controversy, **Czyz et al.[2]** reported a statistically significant difference in fully, partially and non areated NLD between sexes (p = 0.00004). The authoes mentioned that radiographic difference between sexes in aeration of the NLD may represent underlying functional differences in nasolacrimal drainage mechanics or structural differences of the mucosal lining and/or the valvular flaps.

Recommendations:

Prior to any lacrimal drainage surgery especially DCR and artificial duct replacement, MDCT should be performed to have an accurate measurement of the NLD diameters to avoid mucosal injury or duct sliding. Further studies with larger scale of normal volunteers will give more detailed knowledge about the variation of lacrimal system anatomy.

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