Anatomical evaluation of the nasolacrimal groove in 150 dry bones in the Anatolian population

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Abstract

Purpose: In this study, we aimed to evaluate the anatomical features of the nasolacrimal groove in detail by providing a morphological classification based on morphometric evaluations of the nasolacrimal groove.

Methods: A total of 150 sagittal dry bones in the Department of Anatomy, Faculty of Medicine, Istanbul University were evaluated. The length and the width at different points of the nasolacrimal canal were calculated. According to the widths of the nasolacrimal canal 10 different morphological types were revealed.

Results: The length of the canal was found as mean $13.62 \pm 2.42$ mm on the right and $12.44 \pm 2.68$ mm on the left side. The entrance, the base, the upper and the lower thirds of nasolacrimal canal were $6.22 \pm 1.19$ mm, $7.95 \pm 1.85$ mm, $5.85 \pm 1.06$ mm, $6.60 \pm 1.54$ mm, on the right and $6.08 \pm 1.16$ mm, $7.24 \pm 1.64$ mm, $5.45 \pm 1.29$ mm, $6.23 \pm 1.48$ mm, on the left side, respectively. The width of the entrance of the nasolacrimal canal was the narrowest width compared to the base, upper and lower thirds in 7/10 types of 71/150 cranial bones.

Conclusion: This comprehensive morphological classification of the nasolacrimal groove sheds new light on its complex variations. We support that the finding of this study has the potential to improve the precision of diagnostic assessments and guide specific therapeutic interventions for patients with lacrimal drainage disorders.

INTRODUCTION

In the literature, terms such as "lacrical groove" [12], "nasal canal" [23], "nasolacrimal duct" [27] or "nasolacrimal canal" [17, 26, 27] have been used for the nasolacrimal groove formation, but according to Gray's Anatomy [25], the above formations describe different regions. The structure bordered by the anterior lacrimal crest of the maxillary bone and the posterior lacrimal crest of the lacrimal bone is known as the lacrimal groove. Here is located the lacrimal fossa, which houses a pit for the lacrimal sac [10]. When the lacrimal groove is followed inferiorly, it is bordered by the inferior nasal concha and continues as a canal, which is called the nasolacrimal canal. The groove seen along the nasolacrimal canal is known as the nasolacrimal groove (NG). Inside the canal is the nasolacrimal duct, which is responsible for the drainage of tears. Under normal conditions, tears secreted from the lacrimal gland are directed medially and into the upper and lower caruncles with the contraction of the orbicularis oculi muscle. After reaching here, the tear passes first to the lacrimal sac and then to the nasolacrimal duct and reaches the inferior nasal meatus in the nasal cavity [25].

The nasolacrimal duct can be obstructed by acquired or congenital diseases. Congenital nasolacrimal obstruction affecting newborns and infants (5–20%) causes excessive lacrimation (epiphora) due to inadequate drainage of tears from the eye to the nasal cavity, resulting in discomfort and ocular infections [4, 15]. Although obstructions are seen at different points of this lacrimal drainage system, the
most common (70%) obstruction is seen at the entrance at the level of the NG [8]. Historically, the first methods used to treat this condition involved conservative measures, but significant advances in surgery and technology have expanded treatment options [4, 5, 24]. Dacryocystorhinostomy, which can be done externally or endoscopically, is still the backbone of therapy today, with a success rate of over 90% [2, 11, 14].

Although various attempts at nasolacrimal duct recanalization and subsequent intubation with less invasive alternatives have been made over the last twenty years, considerable work has to be done before they can match the success rates of dacryocystorhinostomy surgeries [13].

The use of coronary angioplasty balloons in the treatment of congenital nasolacrimal duct obstructions, punctocanalicularplasty, and revision dacryocystorhinostomy has the potential to greatly alter the health economics of lacrimal drainage diseases in impoverished nations [1, 3, 6]. Therefore, the anatomical features of the NG should be well known in order to determine new interventional techniques or to increase the success rate of existing interventions.

The NG is important for tear drainage and overall ocular health. Despite its importance, there has been little research on the detailed morphometric measurements and morphological aspects of this anatomical component. The current study aims to contribute comprehensive information on the morphometry, morphology, and variability of the nasolacrimal groove. The morphometry of the nasolacrimal groove was analyzed in detail to clarify the anatomy and characteristics of the nasolacrimal groove. We think that the findings obtained from this study may be useful in preoperative planning for interventions in the nasolacrimal duct.

**MATERIAL AND METHODS**

After obtaining the ethics committee approval (number:872856; date:29/04/2022) of our study, the nasolacrimal groove was examined in 150 unilateral dry bones (75 right; 75 left) in the Department of Anatomy, Faculty of Medicine, Istanbul University.

**The morphometric evaluation of nasolacrimal groove**

The morphometric parameters of the NG were first assessed. The width of the nasolacrimal groove was measured at four different points (the transverse distance of the entrance of the nasolacrimal groove (eNG), the base of the nasolacrimal groove (bNG), the upper and lower thirds of the nasolacrimal groove (uNG and lNG) (Fig. 1A). The length of NG was measured from the entrance to the base through the vertical line (Fig. 1B). In our study, measurements were performed using a digital caliper with 0.01 precision. Since it was not clear whether the unilateral dry bones examined belonged to the same sides, a statistical comparison could not be made between the right and left sides.
The evaluation of the precision of morphometric measurements

The reliability of the morphometric measurements in our study was measured in thirty specimens by Technical error of measurement (TEM), Relative technical error of measurement (rTEM) and Coefficient of reliability (R) tests. Firstly, the measurements were repeated by the same researcher (V.O.) and the mean and standard deviation (SD) of the first and second measurements were determined. The TEM value, which is the value of the error magnitude similar to the standard deviation, was calculated. This value differs from the normal standard deviation in that it takes into account both measurement values (first and second measurements). To calculate the TEM value, first, the difference between the first and second measurement was calculated and squared. This value was then divided by 2 times the sample size. Finally, the square root of this value was taken to obtain the TEM value. For the relative technical error of measurement (rTEM) value, the TEM value was divided by the average value obtained from the measurements and multiplied by 100. This value is expressed as a percentage (%). To calculate the coefficient of reliability (R) value, the square roots of TEM and R values were first taken. Then TEM^2 was divided by the square of the standard deviation (SD^2). Finally, the value obtained from 1 was subtracted to obtain the R value. This R value reflects the reliability coefficient, which reflects the proportional change within an individual, independent of measurement error. It ranges from 0 (not reliable) to 1 (completely reliable) [18, 30, 19] (Table 1).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>TEM</th>
<th>rTEM (%)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of NG</td>
<td>1.08</td>
<td>3.52</td>
<td>0.97</td>
</tr>
<tr>
<td>eNG</td>
<td>0.33</td>
<td>1.11</td>
<td>0.98</td>
</tr>
<tr>
<td>bNG</td>
<td>0.48</td>
<td>1.23</td>
<td>0.97</td>
</tr>
<tr>
<td>uNG</td>
<td>0.36</td>
<td>1.09</td>
<td>0.97</td>
</tr>
<tr>
<td>lNG</td>
<td>0.34</td>
<td>0.88</td>
<td>0.98</td>
</tr>
</tbody>
</table>

NG: nasolacrimal groove; eNG: the entrance of the nasolacrimal groove; uNG: upper thirds of the nasolacrimal groove; lNG: lower thirds of the nasolacrimal groove; bNG: the base of the nasolacrimal groove; TEM: Technical Error of Measurement; rTEM: Relative Technical Error of Measurement; R: Coefficient of reliability

The morphological evaluation of nasolacrimal groove

In our study, the following NG types were identified according to the morphometric results of NG: 'cylinder-shaped' or Type 1 when all 4 widths (eNG, bNG, uNG and lNG) were equal; 'hourglass-shaped' or Type 2 when the eNG and bNG were wider than the uNG and lNG; 'barrel-shaped' or Type 3 when the uNG and lNG were equal and wider than the eNG and bNG; 'calyx-shaped' or Type 4, where the eNG was wider than
the other remaining widths (bNG, uNG and ING) of the nasolacrimal groove; 'funnel-shaped' or Type 5, where the eNG was widest but the measured widths gradually decreased towards the bNG; 'pyramid-shaped' or Type 6, where the eNG was narrowest and the widths gradually became wider downwards; 'S-shaped' or Type 7, where the NG had two different directions; 'boat-shaped' or Type 8, where the uNG and ING were wider than the eNG or the nNG; 'volumetric flask-shaped' or Type 9 when the eNG, uNG and ING were smaller than the bNG; 'bottle-shaped' Type 10 when the eNG and the uNG were smaller than the ING and the bNG (Fig. 2).

RESULTS

The length of the canal was found as mean 13.62 ± 2.42 mm on the right and 12.44 ± 2.68 mm on the left side. The widths of the eNG, uNG, ING and bNG were recorded as mean 6.22 ± 1.19 mm, 5.85 ± 1.06 mm, 6.60 ± 1.54 mm, 7.95 ± 1.85 mm on the right and 6.08 ± 1.16 mm, 5.45 ± 1.29 mm, 6.23 ± 1.48 mm, 7.24 ± 1.64 on the left side, respectively. Morphometric findings related to the widths of the NG according to different types are given in Fig. 3.

In our study, we determined that the eNG width of NG was the narrowest compared to the other three widths (bNG, uNG, and ING) in 7 different types (Type 1, Type 3, Type 6–10) of 71/150 bones (Fig. 4 and Fig. 5). Accordingly, the narrowest feature of eNG was found to be most common in Type 9 (volumetric-flask-shaped). The width of the narrowest part of eNG was 3.31mm on the left side. Morphological evaluation was carried out for the classification of NG based on the morphometric data, and a total of 10 different NGs were identified. Of these, 29 were classified as Type 1, thirty-six were Type 2, two were Type 3, eight were Type 4, four were Type 5, sixteen were Type 6, thirteen were Type 7, two were Type 8, twenty-two were Type 9, and twenty were Type 10 (Fig. 4 and Fig. 5). Unlike the previous studies [12], Type 4, Type 6, Type 9 and Type 10 were added in our study and these 4 different types were gained to the scientific literature.

DISCUSSION

The morphometric features of nasolacrimal groove

In the literature the eNG ranged between 4.1-6.1mm [12, 17, 26, 27], middle one-third of NG was reported as mean 8.04 ± 2.05 mm [12] and the bNG was recorded as a mean 5.94 ± 1.28 mm [12]. In our study, the middle part of NG was evaluated into two parts as upper one-third (right: 5.85 ± 1.06 mm; left: 5.45 ± 1.29 mm) and lower one-third (right: 6.60 ± 1.54 mm; left: 6.23 ± 1.48 mm). On the other hand, the eNG and the bNG were calculated as mean 6.15 ± 1.17 mm and 6.41 ± 1.52 mm, respectively. Approximately sixty-four percent of the cadavers examined [27] had the eNG as the shortest width. In our study the shortest width in roughly half of the dry bones (71/150), indicating close rates (Fig. 5). The eNG, which is most commonly affected by nasolacrimal duct obstruction, is reported to be shorter in width in females than in males. As a result, primary acquired nasolacrimal duct obstruction appears to be a complex disease involving multiple causes in females as well as most commonly found in aging females [10]. Fibrous.
alterations in the nasolacrimal duct mucous can be caused by idiopathic inflammatory processes and hormonal abnormalities [10]. Because of the small size of the eNG, material may accumulate, resulting in mucosal tissue adhesion [10]. Although the eNG enlarges with age [8], the combination of these factors that restrict expansion may enhance the prevalence of primary acquired nasolacrimal duct obstruction in aging females. Various openings of the nasolacrimal duct that fit into the bNG of the NG have also been studied in the literature. Kim et al. focused on the lateral wall of the nasal cavity and the distal opening of the nasolacrimal duct in sagittal 36 Korean cadavers [16]. In the cases examined, 4 different openings were found: vertical sulcus (39%), vertical fissure (19%), oblique sulcus (14%) and oblique fissure (28%) [16]. It was reported that different lacrimal folds were found around the sulcus and fissure in 75% of cases [16]. Another study similarly examined the distal opening of the nasolacrimal duct [28]. Tatlısumak et al. examined the distal opening of the nasolacrimal duct morphologically in their study by examining the 15 sagittal cadavers and observed three different types of intranasal nasolacrimal duct openings [28]. They described these morphological findings as pin-point, triangular and slit-like. In the reported studies [16, 28], it has been emphasized that a better understanding of the morphometric and morphological properties of the nasal passage is crucial, especially for use in endoscopic dacryocystorhinostomy, a surgical procedure involving the lacrimal sac and nasal passage [7, 22, 31]. However, surgical interventions in the treatment of nasolacrimal obstructions are performed through the entrance of the NG, i.e. through the caruncles [20, 21, 29, 32]. Therefore, in addition to the morphometric features of NG, we also investigated the incidence of eNG in 150 bones where detailed data are presented in the results section.

The morphological classification of nasolacrimal groove

Ipek et al. classified NG for the first time and found 6 different NG shapes. They recorded the findings as S-shaped (11.3%), boat-shaped (1.6%), hourglass-shaped (11.3%), cylinder-shaped (59.7%), barrel-shaped (11.3%) and funnel shape (4.8%) [12]. Accordingly, Ipek et al. reported cylinder-shaped as the most common type and boat-shaped as the least common type of NG [12]. In the literature on the classification of NG, the width of NG was measured from three different points and 6 different classifications were defined. In our study, we enriched this classification, increased the number of samples and introduced different types to the literature (Fig. 2). In our study, cylinder-shaped or Type 1 was the second most common type (19%) and hourglass-shaped named Type 2 was the most common type (24%). Type 8-boat-shaped was among the least prevalent type in both İpek et al. [12] and our study, accounting for 8% and 1%, respectively. Unlike the study of İpek et al., pyramid-shaped (11%), flask-shaped (15%) and bottle-shaped (14%) were included in our study considering the importance of the eNG parameter [12]. In addition to the morphologic classification of NG, the direction of NG was also investigated [12]. It was reported that 83.3% of the bones examined were inferior perpendicular [12]. This high perpendicularity of the NG demonstrates that retrograde interventions from the nasal cavity to the NG's entrance are not safe. This points out the anatomical significance of eNG.

Because of the high interventional success rate, external or endoscopic dacryocystorhinostomy techniques are favored for nasolacrimal duct obstruction [2, 11, 14]. It is critical to understand the
variations of the nasolacrimal groove reported in our study when designing devices or materials to be used during these interventions, both for endoscopic approaches and when planning new interventions using coronary angioplasty balloons in congenital nasolacrimal duct obstructions [3]. This may boost the success rate of surgical operation planning and may also be beneficial in the creation of new inventive technologies.

This study notes some limitations. First of all, the study uses solely dry bone specimens, which may not precisely represent in vivo anatomical differences and dimensions. Furthermore, the sample size of 150 specimens may not represent the entire diversity of the population, gender or age potentially limiting the findings' generalizability. Furthermore, the morphological classification is just based on morphometric measures, with no consideration given to any functional implications or genetic influences. Finally, the study's single-center design may add bias and limit the proposed classification system's wider use.

In conclusion, the morphological classification of the nasolacrimal canal, which highlights its clinical significance, offers new insight into its varied variants. Our research offers a useful framework for clinicians, anatomists, and researchers to comprehend the variety of the lacrimal system, which we believe has the potential to increase the accuracy of diagnostic evaluations and direct particular therapeutic interventions for patients with lacrimal drainage disorders. Additionally, this classification strengthens our comprehension of the larger significance of nasolacrimal groove variability and establishes the platform for future studies into the genetic, developmental, and functional basis of these morphologic variants. Finally, this classification represents a substantial advancement in our understanding of craniofacial architecture and its complicated interaction with ocular health, paving the path for improved patient care and insights into the broader field of anatomical variation.

**Abbreviations**

NG
nasolacrimal groove
eNG
the entrance of the nasolacrimal groove
uNG
upper thirds of the nasolacrimal groove
lNG
lower thirds of the nasolacrimal groove
bNG
the base of the nasolacrimal groove

**Declarations**

Ethical Approval
Ethics committee approval of our study was received by the Istanbul Medical Faculty Clinical Research Ethics Committee (number:872856; date:29/04/2022).

Competing interests

The authors declare that they have no conflict of interest

Authors' contributions

G.N.C., O.G. wrote the main manuscript text and V.O. prepared figures 1-5 and table 1. All authors reviewed the manuscript

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Availability of data and materials

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References


Figures
Figure 1

Demonstration of measurement parameters related to the nasolacrimal groove. The width of the nasolacrimal groove (A); the width of the entrance of nasolacrimal groove, eNG (black line), the width of the upper third of nasolacrimal groove, uNG (blue line), the width of the lower third of nasolacrimal groove, lNG (red line), the width of the base of nasolacrimal groove, bNG (yellow line). The length of nasolacrimal groove (B); the length of nasolacrimal groove between the entrance and the base points (dashed line) of nasolacrimal canal (red line)
Figure 2

Demonstration of various morphological types of nasolacrimal grooves in human dry bones
Figure 3

The morphometric measurements related to the widths of the nasolacrimal groove according to different ten types

Type 1: 19%
Type 2: 24%
Type 3: 1%
Type 4: 5%
Type 5: 1%
Type 6: 11%
Type 7: 9%
Type 8: 1%
Type 9: 15%
Type 10: 14%

Figure 4

The morphological types of nasolacrimal groove according to their shape. Type 1- cylinder-shaped; Type 2-hourglass-shaped; Type 3-barrel-shaped; Type 4-calyx-shaped; Type 5-funnel-shaped; Type 6-pyramid-shaped; Type 7-S shaped; Type 8-boat-shaped; Type 9-volumetric-flask-shaped; Type 10-bottle shaped
Figure 5

The number of bones with the narrowest width of the entrance of the nasolacrimal groove (eNG) according to the types