The Relationships Between the Nasolacrimal Duct and the Anterior Wall of the Maxillary Sinus

Xiangdong Wang, MD, PhD; Xinjun Chen, MM; Ming Zheng, MD, PhD; Chengyao Liu, MD, PhD; Chengshuo Wang, MD, PhD; Luo Zhang, MD, PhD

Objectives/Hypothesis: To examine the anatomic relationships between the lower end opening into the inferior meatus of the bony nasolacrimal duct (NLD) and the anterior wall of the maxillary sinus.

Study Design: Anatomical investigation.

Methods: A total of 206 individuals were recruited for detailed anatomic investigation of the lower end of the bony NLD and their relation to the anterior wall of the maxillary sinus by high-resolution computed tomography (HRCT) imaging. The observed features were classified as either a fusion type or separation type, according to the HRCT images. Additionally, the angle between the anterior and medial wall of the maxillary sinus was classified as either an anterior mode or lateral mode.

Results: The NLD anatomical fusion type was found in 40.05% and the separation type in 59.95% of the HRCT imaging scans available. The anterior mode of angle between the anterior and medial wall of the maxillary sinus was present in 64.1% of the images, and the lateral mode in 35.9% of the images. In 165 cases of anatomical fusion, the anterior mode of angle was present in 15.8% and the lateral mode in 84.2% of cases. In 247 cases of anatomical separation, the anterior mode was present in 97.2% and the lateral mode in 2.8% of cases.

Conclusions: The surgical anatomy of the lower end of the bony NLD and anterior wall of the maxillary sinus displays varied relationships. Preoperative use of HRCT and an awareness of the particular type of anatomical feature present are likely to aid in planning and performing successful endoscopic medial maxillectomy.

Key Words: High-resolution computed tomography, nasolacrimal duct, maxillary sinus, anatomy, nasal endoscopy.

Level of Evidence: 4

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INTRODUCTION

Various surgical approaches using endoscopic modified medial maxillectomy (EMMM) for treating lesions in the maxillary sinus, pterygopalatine fossa, and infratemporal fossa have been reported over the last decade, as this technique enables preservation of the inferior turbinate (IT) and nasolacrimal duct (NLD).1–9 More recently, using a retrospective study design, Suzuki and colleagues7 have demonstrated that a modified transnasal endoscopic medial maxillectomy through a premaxillary duct approach (MTEMMPDA) was also a safe and effective technique for the resection of inverted papilloma in the maxillary sinus. Both EMMM and MTEMMPDA procedures involve an incision in the medial wall of the maxillary sinus, anterior to the NLD, to expose the angle between the anterior and medial walls of the maxillary sinus, with this angle being located close to the lower end opening into the inferior meatus of the bony NLD. Therefore, a better understanding of the surgical anatomic relationships between the lower end of the bony NLD and the maxillary sinus would aid in the planning and performance of endoscopic medial maxillectomy.

Given the lack of research on the surgical anatomical relationships between the lower end of the bony NLD and the anterior wall of the maxillary sinus, as well as the possible anatomical variations, the aim of the present study was to classify the variations and subtypes of anatomic relationships between the lower end of the bony NLD and the anterior wall of the maxillary sinus, using high-resolution sinus computed tomography (CT) imaging.

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MATERIALS AND METHODS

Study Subjects
A total of 206 patients (115 males and 91 females, aged 18–83 years [mean = 43.12 ± 13.63 years]), attending Beijing Tongren Hospital for endoscopic sinus surgery during the period from August 2014 to November 2014, were enrolled in the study. Subjects with a previous history of maxillary sinus surgery and those with any damage in the medial wall of the maxillary sinus or NLD resulting from trauma or inflammation were excluded. The study was approved by the ethics committee of the Beijing Institute of Otolaryngology, and all subjects provided written informed consent prior to entry into the study.

High-Resolution Computed Tomography Imaging

The anatomical relationships between the anterior border of the bony NLD and the anterior wall of the maxillary sinus: fusion type and separation type. All subjects underwent high-resolution computed tomography (HRCT) imaging with a GE Sytec 4000i CT scanner (General Electric, Boston, MA). Imaging was performed using the axial scan and a multiplanar reconstruction technique. The scanner tube voltage was 120 kV, the tube current 360 mA, the layer thickness 2 mm, and the layer spacing 2 mm. Imaging selection removed the orbital wall from the initial observation, and the NLD was imaged via a plane placed through the bone window.

The actual distance was calculated by the formula: \( \frac{a}{b} \times 10 \text{ mm} \) (Fig. 1).

Anatomical relationships between the angle of anterior/medial walls of the maxillary sinus and bony NLD: anterior mode and lateral mode. A sagittal line was designated along the lateral bony margin of the NLD and used to assist in imaging the anatomical relationship between the angle of anterior/medial walls of the maxillary sinus and the bony NLD. When the angle was located beyond the sagittal line, the feature was classified as the ‘lateral mode’ (Fig. 2A), and when the angle was located within the sagittal line, the observed feature was classified as the ‘anterior mode’ (Fig. 2B). The relationship between the characteristics of the bony NLD and the anterior/medial walls of the maxillary sinus angle was recorded in both nostrils for each patient.

The distance between the anterior wall of the maxillary sinus and the anterior border of the bony NLD. The transverse section of the CT scan of the lower end of the bony NLD was placed in Adobe Photoshop CC 2018 (Adobe Systems, Inc., San Jose, CA). The distance (a) between the anterior wall of the maxillary sinus and the anterior border of the bony NLD was measured. The scale (b) was 10 mm, and the actual distance was calculated by the formula: \( \frac{a}{b} \times 10 \text{ mm} \) (Fig. 1).

Statistical Methods
All statistical analyses were performed using the SPSS Statistics for Windows, version 17.0 software package (IBM, Armonk, NY). The \( \chi^2 \) test and Fisher exact test were used to
assess the significance of any differences observed between males and females. The Wilcoxon rank sum test and $t$ test were used to compare the distance between the anterior maxillary wall and the NLD of males and females, with a $P$ value < .05 considered to be statistically significant.

**RESULTS**

**Relationship Between the NLD and Anterior Wall of the Maxillary Sinus: Fusion Type and Separation Type**

A total of 412 sets of HRCT imaging data were obtained from the 206 enrolled subjects. Table I summarizes the relationships observed between the lower end of the bony NLD and the anterior wall of the maxillary sinus.

Assessment of the relationship between the lower end of the NLD and anterior wall of the maxillary sinus demonstrated that in males the bilateral anatomical fusion type was present in 27.83% (32/115) of the subjects, the bilateral anatomical separation type in 56.52% (65/115) of the subjects, and the bilateral anatomical mixed type in 15.65% (18/115) of the subjects. In comparison, the bilateral anatomical fusion type was present in 37.36% (34/91) of the female subjects, the bilateral anatomical separation type in 46.15% (42/91) of the subjects, and the bilateral anatomical mixed type in 16.48% (15/91) of the subjects. The proportion of overall bilateral inconsistency was 16.02%, with no significant difference between males and females (Table II).

**Relationship Between the Angle of the Anterior/Medial Walls of the Maxillary Sinus and NLD: Anterior Mode and Lateral Mode**

Assessment of the anatomical relationships between the angle of the anterior/medial walls of the maxillary sinus and the bony NLD demonstrated that in 35.92% (148/412) of the HRCT images and the anatomical anterior mode in 64.08% (264/412) of the images. Similarly, the bilateral anterior mode was present in 56.80% (117/206) of the subjects, the bilateral lateral mode in 28.64% (59/206) of the subjects, and the anatomical mixed mode in 14.56% (30/206) of the subjects.

There was also bilateral inconsistency in cases of the anterior mode and lateral mode. Among the 115 male subjects, 60.00% (69/115) demonstrated bilateral anterior mode, 25.22% (29/115) bilateral lateral mode, and 14.78% (17/115) mixed mode. In comparison, among the 91 female subjects, 52.75% (48/91) demonstrated bilateral anterior mode, 32.97% (30/91) bilateral lateral mode, and 14.29% (13/91) mixed mode, with no significant differences between males and females (Table II).

**The Distance Between the Anterior Wall of the Maxillary Sinus and the Anterior Border of the NLD**

In the cases of anatomical separation, the distance between the anterior wall of the maxillary sinus and the anterior border of the NLD in the males was found to be $2.0 \pm 1.2$ mm (range, 0.1–8.2 mm), which was significantly higher than the distance of $1.6 \pm 0.8$ mm (range, 0.3–3.6 mm) ($P < .05$) in females.

**Clinical Case Report**

Representative cases for clinical indications of the separation type and fusion type are shown in Figure 3 and Figure 4, respectively. Figure 3 shows that the IT, NLD, and medial wall of the maxillary sinus were pushed together medially after making an incision at the location of the angle between the anterior and medial walls of the maxillary sinus in the separation type (anterior mode) for the purpose of exposing the maxillary sinus. Figure 4 shows that the IT bone was cut to make an incision between the NLD and anterior wall of the maxillary sinus for the purpose of exposing the maxillary sinus in the fusion type (lateral mode).
In this study, HRCT imaging of the maxilla revealed a varied surgical anatomy of the lower end of the bony NLD in relation to the anterior wall of the maxillary sinus, classified according to fusion/separated type and the angle between the anterior and medial wall of the maxillary sinus classified as either an anterior/lateral mode. Based on these classifications, we found that the fusion-type anatomy was present in 40.05% of the subjects and the separation-type anatomy in 59.95% of the subjects. Furthermore, although the lateral mode of the angle between the anterior and medial walls of maxillary sinus was more prevalent in the subjects with fusion-type anatomy (84.24%), the anterior mode of the angle was more prevalent in the subjects with separation-type anatomy (97.17%).

Other studies have reported on the relationships between the NLD and ostium of the maxillary sinus or the anterior attachment of the IT.10,11 In one recent study, Simmen and colleagues12 assessed the relationship between the anterior maxillary wall and lacrimal duct relationship by CT analysis, as a way of accessing the maxillary sinus through the prelacrimal window. The authors reported that although a distance of >7 mm between the anterior maxillary wall and the anterior border of the lacrimal duct was present in 12.5% of maxillary sinuses, and would provide a straightforward prelacrimal window access (PLWA), a distance < 7 mm and >3 mm was present in 56.5% of sinuses, and would make surgical access more demanding. However, in 31.5% of maxillary sinuses, the distance was ≤3 mm, and in those patients, PLWA would be difficult to accomplish without transecting the NLD along with a significant amount of bone removal.12 Thus, based on the findings from the present study, it can be calculated that more than 70% of the cases investigated by Simmen and colleagues12 could be classified as separation type, which was higher than about 60% of the subjects with this classification in our study. Furthermore, as the distance between the anterior wall of the maxillary sinus and the anterior border of the NLD of most cases in the study by Simmen and colleagues12 was > 3 mm, which was also longer than the mean of 2 mm found in our study, it is possible that these may reflect anatomical differences between Western and Chinese subjects. In another recent study, Sieskiewicz and colleagues13 reported that the angle between the lacrimal duct and nasal floor was negatively correlated with lacrimal recess.13 However, the current study provided a detailed classification of the relationship between the NLD and the anterior wall of the maxillary sinus, which was mostly consistent with the relationship between the angles of the anterior/medial walls of the maxillary sinus and NLD.

Studies utilizing EMMM1–9 often involved removal of the anterior bony portion of the IT to expose the NLD, and the medial wall of the maxillary sinus was subsequently drilled with a burr drill to expose the maxillary sinus.

DISCUSSION

In this study, HRCT imaging of the maxilla revealed a varied surgical anatomy of the lower end of the bony NLD in relation to the anterior wall of the maxillary sinus, classified according to fusion/separated type and the angle between the anterior and medial wall of the maxillary sinus classified as either an anterior/lateral mode. Based on these classifications, we found that the fusion-type anatomy was present in 40.05% of the subjects and the separation-type anatomy in 59.95% of the subjects. Furthermore, although the lateral mode of the angle between the anterior and medial walls of maxillary sinus was more prevalent in the subjects with fusion-type anatomy (84.24%), the anterior mode of the angle was more prevalent in the subjects with separation-type anatomy (97.17%).

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Fig. 3. (A) A bone cyst in the left maxillary sinus with the separation type of nasolacrimal duct (NLD). (B) Intraoperatively, the inferior turbinate bone and NLD (black asterisk, NLD was exposed partly), as well as the medial wall of the maxillary sinus (yellow asterisk) were pushed together medially after making an incision at the location of the angle between the anterior and medial walls of the maxillary sinus.

Fig. 4. (A) Inverted papilloma in a left maxillary sinus with the fusion type of the nasolacrimal duct (NLD). Intraoperatively, the inferior turbinate bone was cut to expose the NLD (yellow asterisk), and then an incision was made between the medial (white asterisk) and anterior walls of the maxillary sinus for the purpose of exposing the maxillary sinus with the fusion type of the NLD (B).
The surgical anatomy of the lower end of the bony NLD and the anterior wall of maxillary sinus displays varied relationships. Preoperative use of HRCT and an awareness of a particular anatomical feature present between the bony NLD and the anterior wall of maxillary sinus are likely to aid in planning and performing successful endoscopic medial maxillectomy.

CONCLUSION

The surgical anatomy of the lower end of the bony NLD and the anterior wall of maxillary sinus was not performed in these studies. In this regard, the present study is different in that several anatomic relationships between the middle distal portion of the bony NLD and the anterior wall of the maxillary sinus have been investigated. The finding by presurgery HRCT imaging of whether the lower end of the bony NLD is fused or separate is likely to substantially aid in planning surgical intervention/s involving the maxillary sinus. Thus, for example when the separation-type anatomy is present, a chisel can be used to make an incision at the location of the attachment of the anterior bony portion of the IT together with the IT mucosa and NLD. However, when the fusion type is present, the anterior bony portion of the IT cannot usually be preserved, and the medial wall of the maxillary sinus needs to be opened by drilling underneath the NLD, not at the attachment of the anterior bony portion of the IT, as the latter approach may damage the NLD or pyriform aperture medially or laterally, respectively.

The prelacrimal recess has been used by some authors to describe the angle between the anterior and medial walls, which is located in front of the NLD and is similar to the PLWA described by Simmen et al. In the present study, we found that the anterior-type prelacrimal recess was present mostly in the separation type of the NLD, and therefore the concept of the prelacrimal recess applied to approximately 60% but not all subjects investigated. As discussed above, it was easy to access into the maxillary sinus through the angle between the anterior and medial walls in cases of the anterior mode (in the separation type), but relatively difficult in cases of the lateral mode (in the fusion type). However, a limitation of this study is that a relatively small study population was selected from a single medical center. Thus, it is also possible that individuals, who despite not having a known history of damage to their NLDs, may have had undiagnosed traumatic or inflammatory events that could have affected their anatomy.

BIBLIOGRAPHY