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Radiological assessment of the lateral osteotomy line–lacrimal system distance on three-dimensional models

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ABSTRACT

Aims: One of the most commonly performed operations in aesthetic, plastic, and reconstructive surgery is rhinoplasty, the aim of which is to construct an altered nasal shape, either for aesthetic or functional reasons. The lateral osteotomy is the most traumatic step of rhinoplasty, and is generally difficult to perform. The lacrimal system can be damaged during the lateral osteotomy procedure. In this study, we aimed to measure the distance between the lacrimal system and the lateral osteotomy line, and to determine the safe and ideal osteotomy level, which is very important in rhinoplasty procedures. We also evaluated the safe relationship of this osteotomy level with the lacrimal system by constructing a three-dimensional model.

Materials and methods: The three-dimensional models were constructed on axial planes using paranasal computed tomographic (CT) images of 40 male and 40 female patients. The 'lateral osteotomy model' was designed in three dimensions. The axial CT images were obtained from the model. On the CT images, the distance between the lateral osteotomy line and the lacrimal system was assessed by measuring three distances. The first was the distance between the anterior lacrimal crest and the lateral osteotomy line. The second was the distance from the midpoint between the anterior lacrimal crest and the inferior meatus to the lateral osteotomy line. The third was the distance between the opening of the lacrimal canal to the inferior meatus and the lateral osteotomy line.

Results: No lacrimal system injury was seen on any of the models. The shortest distance was found between the anterior lacrimal crest and the lateral osteotomy line, measured at 4.5 mm and 5.0 mm in the female and male patients, respectively.

Conclusion: Performing the lateral osteotomy meticulously while paying attention to remaining anterior to the medial canthal ligament will not lead to any lacrimal system injury.

1. Introduction

Rhinoplasty, one of the most commonly performed operations in aesthetic, plastic, and reconstructive surgery, aims to construct an altered nasal shape (Rohrich and Ahmad, 2011). The procedure is classified into two main groups: 'aesthetic rhinoplasty', which is performed to change the nasal appearance, and 'functional rhinoplasty', which is carried out to improve nasal function. However, both function and aesthetics are based on morphology, so these two concepts are inseparable and interdependent.

It is essential to carry out a complete and thorough preoperative investigation when the decision to operate is made, in order to identify the deformities of the cartilaginous and bony structures. Anatomical corrections should be made intraoperatively, and

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potential postoperative complications should be assessed and necessary measures taken in order to achieve the desired results (Gunter and Rohrich, 1988; McCarthy, 1990; Toffel, 1992).

Rhinoplasty comprises the following operative steps: incision, elevation of the skin, resection of the dorsal hump, reconstruction of the septum when necessary, evaluation of the projection of the nasal tip, lateral and medial osteotomies, and, finally, closure. Among these steps, the most traumatic and difficult to learn is the lateral osteotomy (McCarthy, 1990; Rees, 1994).

The lateral osteotomy forms part of both aesthetic and functional rhinoplasties. It is performed as a basic step in rearrangement of the nasal contour, narrowing of the nasal base, and in correcting the open-roof deformity that occurs after hump resection (Rohrich et al., 1997; Giacomarra et al., 2001). Complications associated with lateral osteotomy are bleeding, edema, infection, anosmia, intracranial damage, aesthetic deformity, stair step deformity, epiphora, and narrowing of the functional airway (Holt et al., 1987; Rees, 1994).

Epiphora develops as the result of an injury to the lacrimal system during the osteotomy procedure. The anatomical proximity of the lacrimal system to the lateral osteotomy line is well known. The difficulty in performing the lateral osteotomy during the training process, and consequently not paying attention to this close anatomical relationship, increases the incidence of epiphora development (Flanahan, 1978).

One of the preferred methods for a thorough preoperative evaluation is computed tomography (CT) imaging, which has undergone many technological advancements. While only one detector was present in the first-generation CT devices, this number has increased over time, with the development of MDCT (multidetector computed tomography) (Bae and Whiting, 2005; Flohr et al., 2005). In the fifth-generation devices, the movements of the tube and detectors were eliminated, with the gantry converted to a very large X-ray tube. The most significant advancement in MDCT has been in the alignment of detectors in several rows. The slice thickness is within the range 0.5–0.62 mm, with the thinner slices increasing the resolution, and enabling volume reformatting and three-dimensional reconstructions (Grenier et al., 2002; Mahesh, 2002; Kalender, 2006). Multiplanar reformation (MPR) enables conversion between the axial, coronal, and sagittal planes, or planes at other angles within the maxillofacial region. Volume rendering technique (VRT) is a software application for construction of three-dimensional images. All information within the raw data is used during the process, with the entire volume of data being projected (McNamara and Kapila, 2006).

In this study, we aimed to measure the distance between the lacrimal system and the lateral osteotomy line, and to determine the safe and ideal osteotomy level, which is very important in rhinoplasty procedures. We also evaluated the safe relationship of this osteotomy level with the lacrimal system by constructing a three-dimensional model.

2. Materials and methods

2.1. Patient selection

For this study, patients with axial smooth CT (computed tomography) images of 0.6 mm thickness for the paranasal region in the archives of the Radiology Department of Süleyman Demirel University Medical Faculty for the period March to September 2011 were investigated retrospectively. A total of 80 patients (40 males and 40 females) within an age range of 18–45 years were included in the study.

2.2. Computed tomography imaging and the construction of the three-dimensional model

Paranasal CT imaging was performed using a 128-section MDCT device (Somatom Definition AS Plus; Siemens). Axial smooth images were obtained on the lateral scanogram by the X-ray tube, with 0.6 mm collimation and 300 ns gantry rotation time, using 120 and a mean of 100 eff-mns for 180-FOV, 7-s shots. The obtained images were analyzed by sending them to a Leonardo workstation (Siemens Medical Solutions, Forchheim, Germany). The

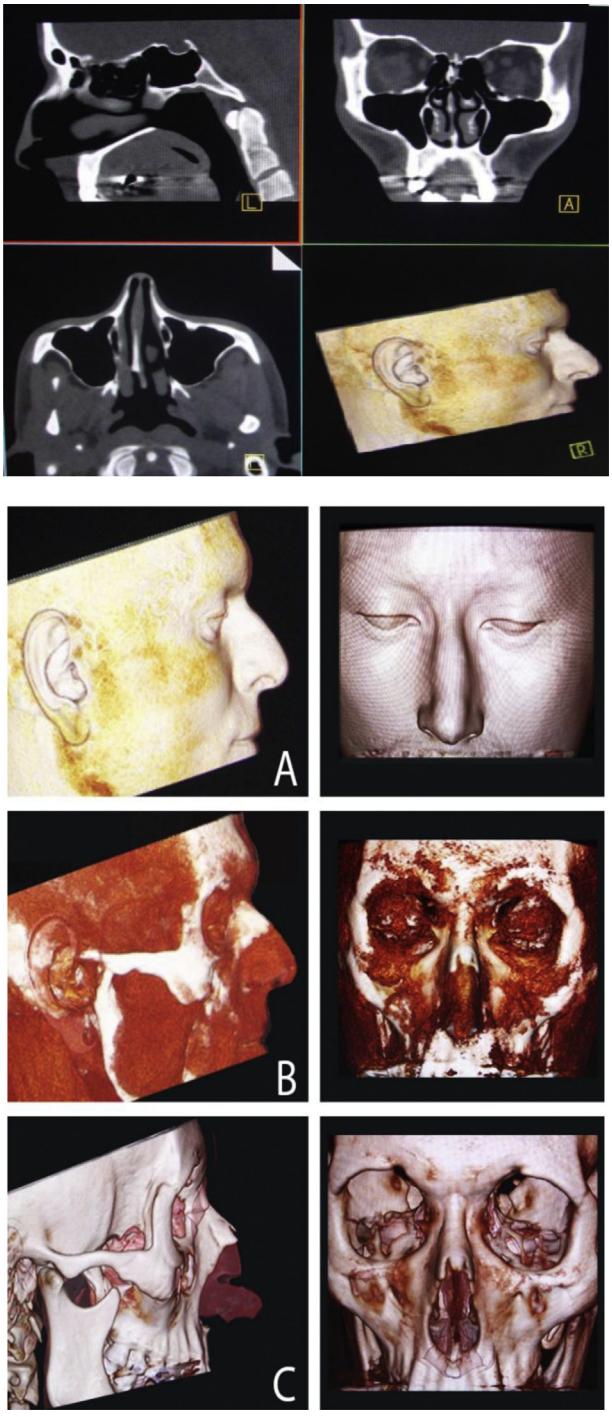

Fig. 1. Construction of the three-dimensional soft tissue images from the axial, coronal, and sagittal images by using a VRT software program.

satisfactoriness of the image quality in the acquired images was then evaluated. The coronal and sagittal planar MPR reconstruction images (0.6 mm thickness) were obtained from the axial images. Three-dimensional images (soft and bony tissues) were then generated with these images using VRT (Fig. 1).

The Frankfort horizontal plane and the nasal aperture were identified in the sagittal plane on the three-dimensional bone images. The starting point for the lateral osteotomy was marked as 3 mm cranial to the widest part of the nasal aperture on the anterior image (Fig. 2a–c). The end point of the lateral osteotomy was marked as passing through the anterior border of the attachment site of the medial canthal ligament, also identifiable on the image (Fig. 2a, b). The lateral osteotomy model was then depicted, extending through the frontal process of the maxillary bone (the junctional line of the maxillary and nasal planes), identified by the intersection of lines passing through these points. Segmentation of the bone tissue was carried out throughout the intersecting lines to form the osteotomy line. After segmentation, the osteotomy line was created (Fig. 2d–f). The bone and soft tissue images from different directions were obtained from the model (Figs. 3 and 4). The axial and coronal images were generated by the MPR software program from the constructed model using the three-dimensional images of the lateral osteotomy line in the axial plane at 0.6 mm thickness.

2.3. Interpretation of CT findings

All sections on the 0.6 mm axial CT images obtained from the three-dimensional model were investigated for the presence of lacrimal duct injury. Measurements of the distance between the lacrimal system and the lateral osteotomy line were made both on the right and the left sides and at three different points (Fig. 5), as follows:

1. The distance between the lateral osteotomy line (point A) and the anterior lacrimal crest.
2. The distance between the lateral osteotomy line (point B) and the midpoint of the distance between the anterior lacrimal crest and the opening site of the nasolacrimal canal to the inferior meatus (nasolacrimal canal).
3. The distance between the lateral osteotomy line (point C) and the opening site of the nasolacrimal canal to the inferior meatus.

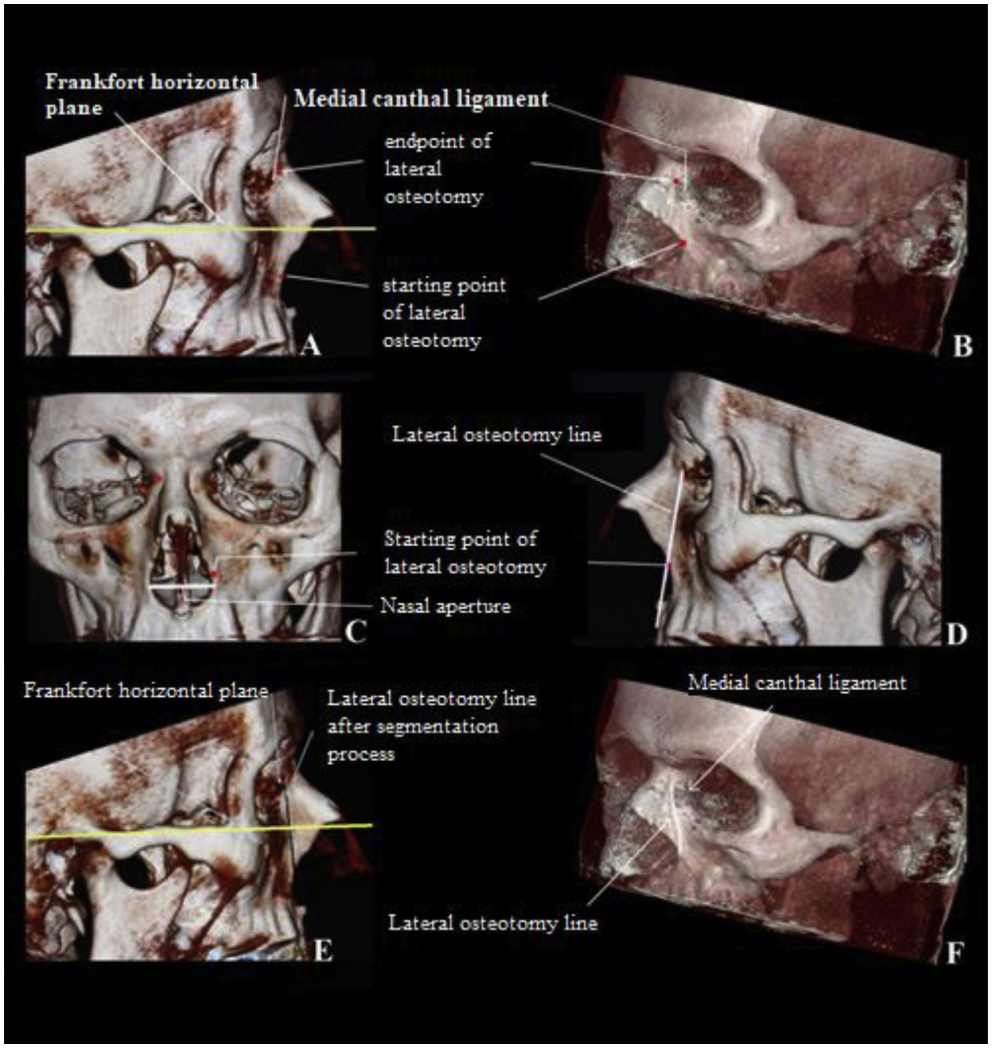

Fig. 2. Planning and forming the lateral osteotomy model on the three-dimensional image.

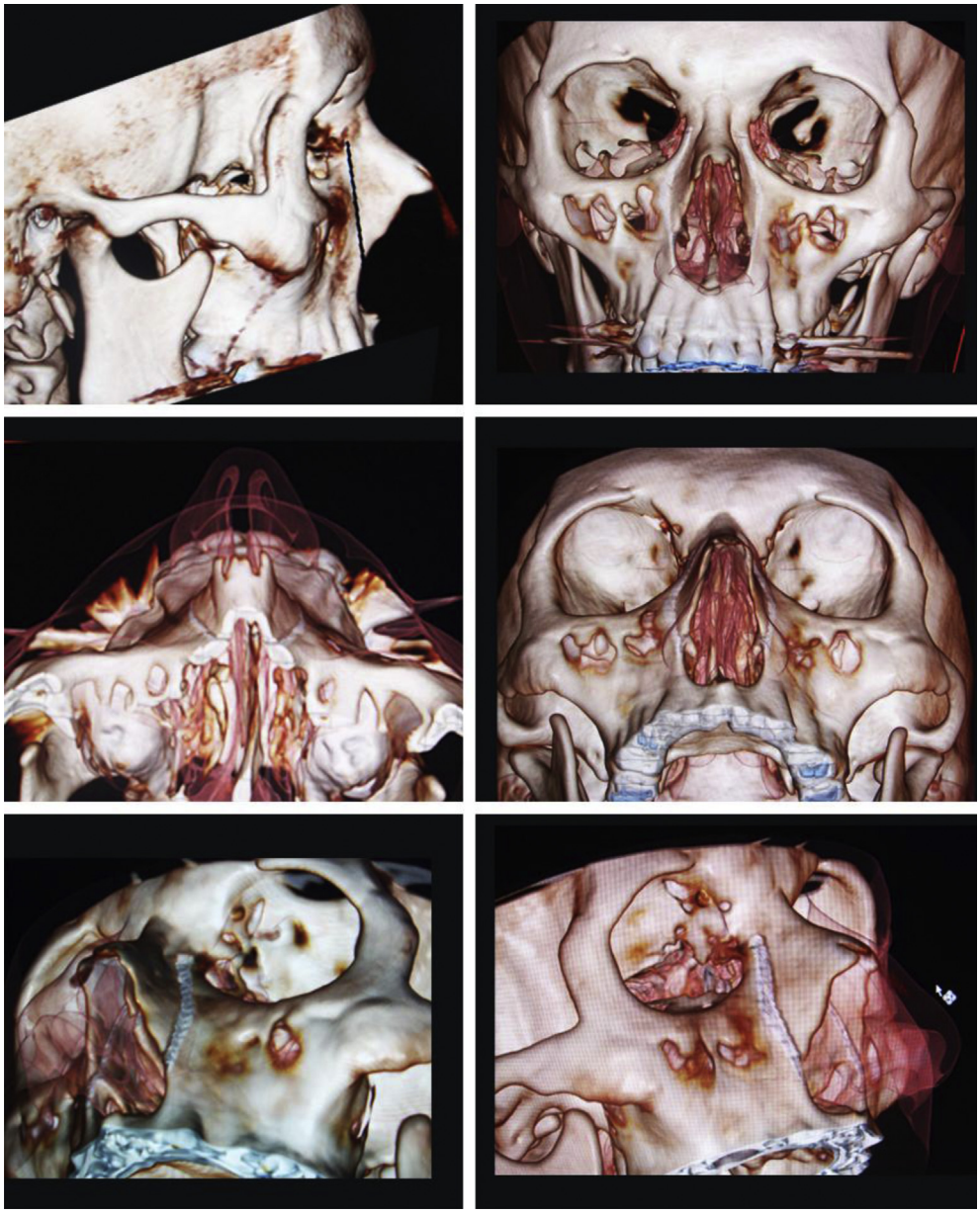

Fig. 3. Bony tissue views of the three-dimensional lateral osteotomy model from different directions.

CT images were interpreted by a single radiologist and the interpretation time lasted 5–10 min. The measurements were calculated in mm.

2.4. Statistical analysis

SPSS 15.0 statistical software was used for analysis. Separate mean values, maxima, minima, and standard deviations were determined from three points on the right and left sides. The t-test was used to determine whether there was a significant difference between the right and left sides, and between males and females. $p < 0.05$ was considered as statistically significant.

3. Results

When the data for all 40 female patients were analyzed, it was found that the average distance between the lateral osteotomy line and the anterior lacrimal crest was 6.0 ± 0.8 mm (4.5–7.5 mm) on the right side and 6.0 ± 0.7 mm (4.5–7.4 mm) on the left side. The average distance between the lateral osteotomy line and the midpoint between the anterior lacrimal crest and inferior meatus was 7.4 ± 1.0 mm (5.5–9.8 mm) on the right side and 7.4 ± 1.0 mm (5.4–10.0 mm) on the left side. The average distance between the lateral osteotomy line and the opening site of the nasolacrimal canal to the inferior meatus was 9.8 ± 1.5 mm (6.8–12.5 mm) on the right side and 9.8 ± 1.5 mm (7.0–12.7 mm) on the left side. The results on the right and left sides for all three measurement sites were statistically similar ($p > 0.05$) (Table 1; Fig. 6).

For the 40 male patients, it was found that the average distance between the lateral osteotomy line and the anterior lacrimal crest was 6.7 ± 0.8 mm (5.3–8.5 mm) on the right side and 6.7 ± 0.8 mm (5.0–8.4 mm) on the left side. The average distance between the lateral osteotomy line and the midpoint between the anterior lacrimal crest and inferior meatus was 8.3 ± 0.93 mm

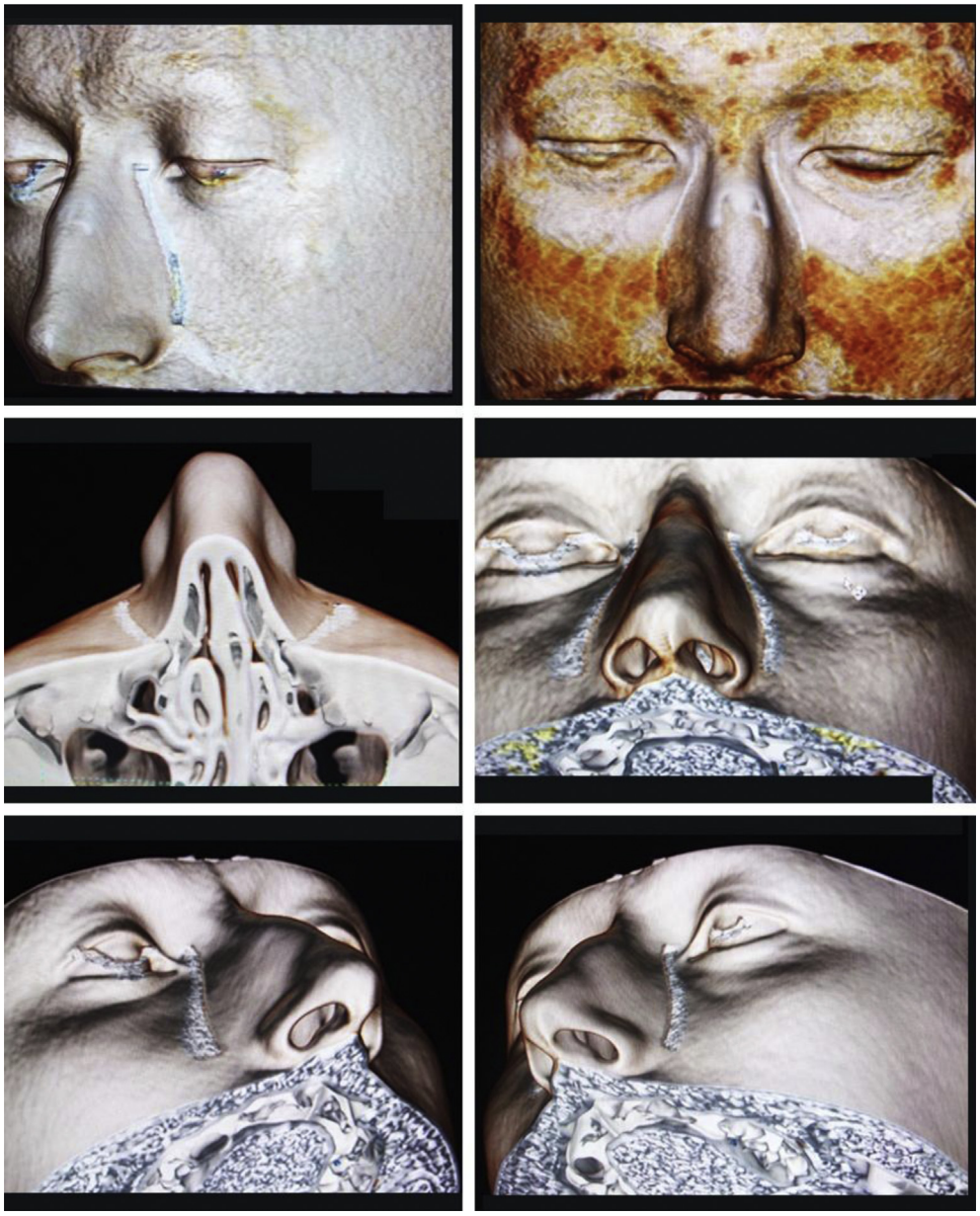

Fig. 4. Soft tissue views of the three-dimensional osteotomy model from different directions.

(6.2–10.0 mm) on the right side and 8.3 ± 0.9 mm (6.3–10.8 mm) on the left side. The average distance between the lateral osteotomy line and the opening site of the nasolacrimal canal to the inferior meatus was 10.6 ± 1.2 mm (8.5–13.7 mm) on the right side and 10.5 ± 1,2 mm (8.4–12.9 mm) on the left side. The results on the right and left sides for all three measurement sites were statistically similar ($p > 0.05$) (Table 2; Fig. 7).

When the measurements for the right and left sides were compared between females and males, it was found that there were statistically significant differences between females and males on both the right and left sides for all three measurements ($p < 0.05$) (Table 3; Figs. 8 and 9).

When all of the axial images in the three-dimensional lateral osteotomy model — planned by considering the anterior lacrimal crest (the attachment site of the medial canthal ligament) as the reference point — were examined individually, no injury to the lacrimal sac or lacrimal canal was detected in any section.

4. Discussion

For our study, we created three-dimensional images from axial and coronal sections of patients in whom paranasal CT imaging had been performed. A lateral osteotomy model was then created on the bony tissue at the Frankfort horizontal plane. The distance between the lateral osteotomy line and the lacrimal system was measured after obtaining a two-dimensional axial CT image from the model. The safety margin for the performed lateral osteotomy was evaluated by considering the nasal aperture and the medial canthal ligament as reference points. No differences were found between the sides in both females and males; however, when the same sides were compared between genders, the differences were statistically significant. Performing the lateral osteotomy by taking the medial canthal ligament as the reference point was considered to be safe regarding lacrimal system injury, because we identified no lacrimal sac or lacrimal canal injury in any section while

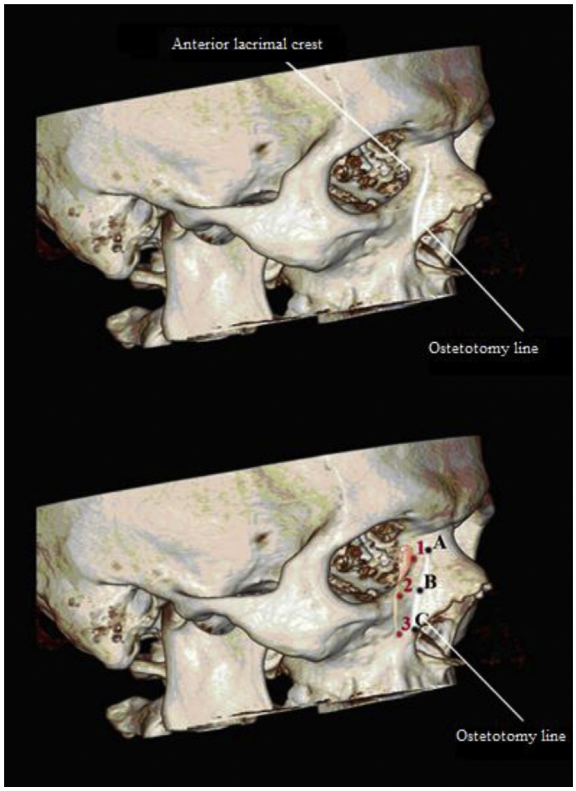

Fig. 5. Schematic view of the three points used for measurement of the distance between the lacrimal system and the lateral osteotomy line, incorporating an image of the lacrimal sac and the nasolacrimal canal inside the bone. **Point 1**: anterior lacrimal crest; **Point 2**: midpoint of the distance between the anterior lacrimal crest and the opening site of the nasolacrimal canal into the inferior meatus (nasolacrimal canal); **Point 3**: opening site of the nasolacrimal canal into the inferior meatus; **Point A**: endpoint of the lateral osteotomy; **Point B**: midpoint between Point A and Point C; **Point C**: starting point of the lateral osteotomy.

Table 1
Measurement results for the female patients ($n = 40$).

	Right lateral osteotomy line in mm (and range)	Left lateral osteotomy line in mm (and range)	p
Anterior lacrimal crest	6.0 ± 0.8 (4.5–7.5)	6.0 ± 0.7 (4.5–7.4)	>0.05
Midpoint between the anterior lacrimal crest and the inferior meatus	7.4 ± 1.0 (5.5–9.8	7.4 ± 1.0 (5.4–10.0)	>0.05
Opening site of the nasolacrimal canal to the inferior meatus	9.8 ± 1.5 (6.8–12.5)	9.8 ± 1.5 (7.0–12.7)	>0.05

examining the individual axial images in our three-dimensional lateral osteotomy model.

Rhinoplasty is an operative procedure commonly performed by plastic surgeons to restore the normal functioning of the nose or to enable the patient to acquire a desired appearance (Swartout and Toriumi, 2007; Sajjadian and Guyuron, 2010; Rohrich et al., 2011). The procedure has certain steps, finalized by medial and lateral osteotomies, and roof closure.

Lateral osteotomy is the last of these steps for finalizing the shaping of the nose. It is performed during both functional and aesthetic rhinoplasties, and is the basic approach in rearranging the nasal contour, narrowing the base of the nose, and correcting open roof deformity following resection of the hump. However, it is also the most traumatic and difficult to learn step of the rhinoplasty procedure (Krause, 2002; Rohrich et al., 2003; Sinha et al., 2007). Currently, lateral osteotomy is usually carried out endonasally or percutaneously. The conventional procedure is performed either by a continuous osteotomy, lateral to the bony pyramid, or by creating a perforation. In the endonasal technique, the osteotomy starts from the nasal aperture and ends anterior to the medial canthal aperture. A perforating external nasal osteotomy is performed using a thin osteotome externally, after making an incision in the region of the nasofacial groove inferior to the medial canthal ligament (Giacomarra et al., 2001).

Endonasal continuous lateral osteotomies are of three types — 'low to high', 'low to low', and 'double level'. Low-to-low osteotomy starts from a point 3–4 mm above the inferolateral part of the pyriform aperture and ends just anterior to the medial canthal ligament. The straight osteotomy line lies along the frontal process of the maxillary bone (Becker et al., 2000; Giacomarra et al., 2001; Sullivan and Fletcher, 2001; Bracaglia et al., 2004; Dobratz and Hilger, 2010). Since the osteotomy line lies close to the lacrimal system, we constructed our model by using the low-to-low osteotomy type, starting from a point 3 mm above the inferolateral part of the nasal pyriform aperture. Because we identified no injury in any model during measurements taken between the lateral osteotomy line at the lower level and the opening site of the nasolacrimal canal to the inferior meatus, we considered it to be safe. The safety margins were found to have means of 9.8 mm (range 6.8–12 mm) on the right side and 9.8 mm (range 7.0–12.7 mm) on the left side for females, and 10.6 mm (range 8.5–13.7 mm) on the right side and 10.5 mm (range 8.4–12.9 mm) on the left side for males.

Cochran et al. stated that one of the most familiar complications of lateral osteotomy is temporary epiphora, a lacrimal system condition that develops due to edema, but recovers after edema regresses. Permanent epiphora, on the other hand, can occur due to lacrimal system injury, and necessitates dacryocystorhinostomy. The authors suggested that the risk of lacrimal system injury is higher when a subperiosteal tunnel is created and low-to-low osteotomy is performed using a saw (Cochran and Landecker, 2008). We constructed a three-dimensional low-to-low osteotomy model and used this to evaluate the safety margin regarding the lacrimal system. We encountered no lacrimal system injuries in our study on 80 models.

The anatomy of the lacrimal system and the potential for injury need to be well understood. It is known that the lacrimal system is close to the lateral osteotomy line and it has therefore been reported that lacrimal system injury might occur during rhinoplasty (Sachs, 1984). The lacrimal system consists of soft tissues, the lacrimal bone, the frontal process of the maxilla, and the nasal bones. The lacrimal sac is located within the lacrimal fossa. During the lateral osteotomy procedure, the lacrimal canal is protected by the bone and the lacrimal sac is protected by the medial canthal tendon. It has been reported that this protection is insufficient, and a risk of damage occurs when the medial canthal tendon is injured (Cies and Baylis, 1976; Sachs, 1984). In our study, the lateral osteotomy line was planned to remain anterior to the medial canthal ligament. No significant differences were found when the right and left sides were compared in both the females and male ($p > 0.05$); this showed that the safety margins for lateral osteotomies were similar on both the right and the left sides. The significant differences found in our study when the same sides were compared in terms of gender ($p < 0.05$) were considered to have originated from anatomical differences between the genders.

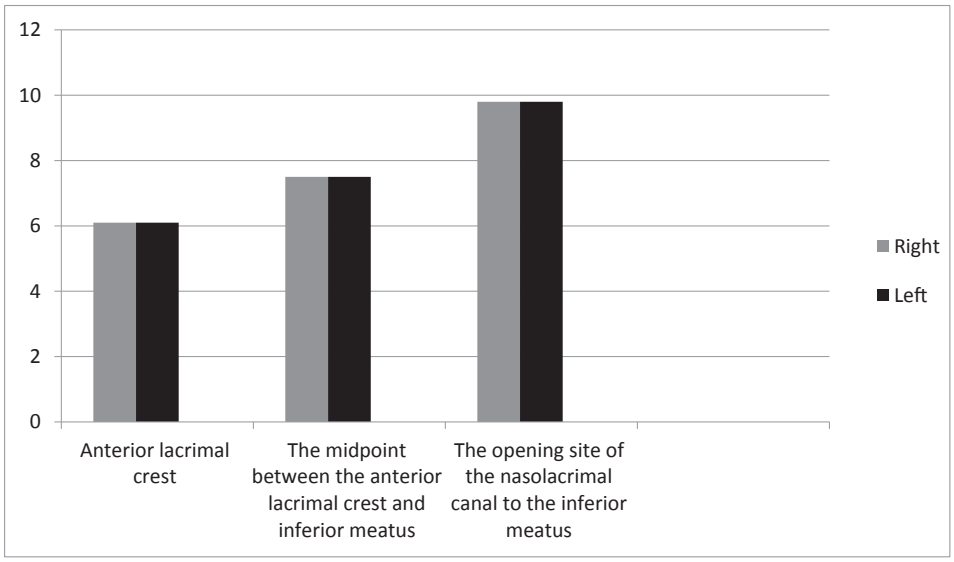

Fig. 6. Measurement results for the average distances to the lateral osteotomy line in female patients ($n = 40$).

Table 2
Measurement results for the male patients ($n = 40$).

	Right lateral osteotomy line in mm (and range)	Left lateral osteotomy line in mm (and range)	p
Anterior lacrimal crest	6.7 ± 0.8 (5.3–8.5)	6.7 ± 0.8 (5.0–8.4)	>0.05
Midpoint between the anterior lacrimal crest and the inferior meatus	8.3 ± 0.93 (6.2–10.0)	8.3 ± 0.9 (6.3–10.8)	>0.05
Opening site of the nasolacrimal canal to the inferior meatus	10.6 ± 1.2 (8.5–3.7)	10.5 ± 1.2 (8.4–12.9)	>0.05

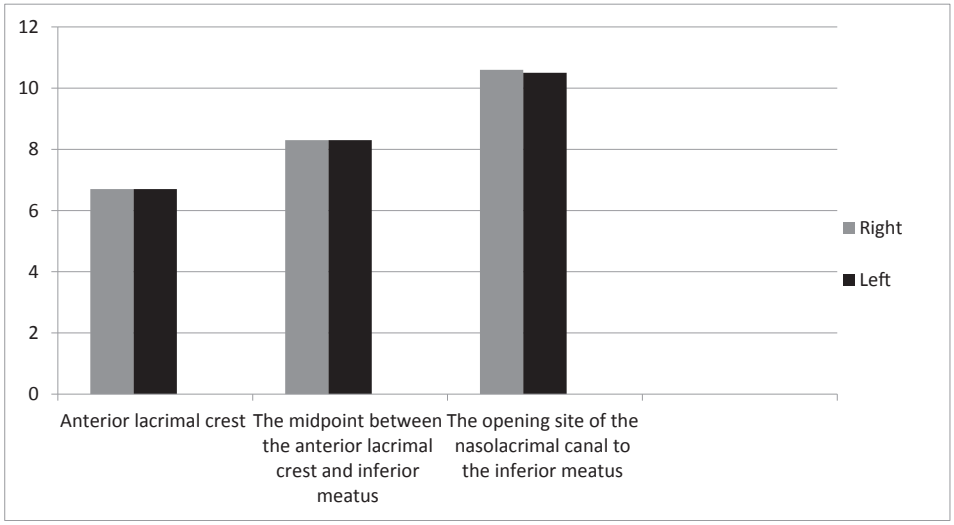

Fig. 7. Measurement results for the average distances to the lateral osteotomy line in male patients ($n = 40$).

Table 3
Comparison of distances to the lateral osteotomy line between females and males on the right and left sides.

	Male patients	Female patients	p
Right			
Anterior lacrimal crest (mm)	6.7 ± 0.8 (range 5.3–8.5)	6.0 ± 0.8 (range 4.5–7.5)	<0.05
Midpoint between the anterior lacrimal crest and the inferior meatus (mm)	8.3 ± 0.9 (range 6.2–10.0)	7.4 ± 1.0 (range 5.5–9.8)	<0.05
Opening site of the nasolacrimal canal to the inferior meatus (mm)	10.6 ± 1.2 (range 8.5–13.7)	9.8 ± 1.5 (range 6.8–12.5)	<0.05
Left			
Anterior lacrimal crest (mm)	6.7 ± 0.8 (range 5.0–8.4)	6.0 ± 0.7 (range 4.5–7.4)	<0.05
Midpoint between the anterior lacrimal crest and the inferior meatus (mm)	8.3 ± 0.9 (range 6.3–10.8)	7.4 ± 1.0 (range 5.4–10.0)	<0.05
Opening site of the nasolacrimal canal to the inferior meatus (mm)	10.5 ± 1.2 (range 8.4–12.9)	9.8 ± 1.5 (range 7.0–12.7)	<0.05

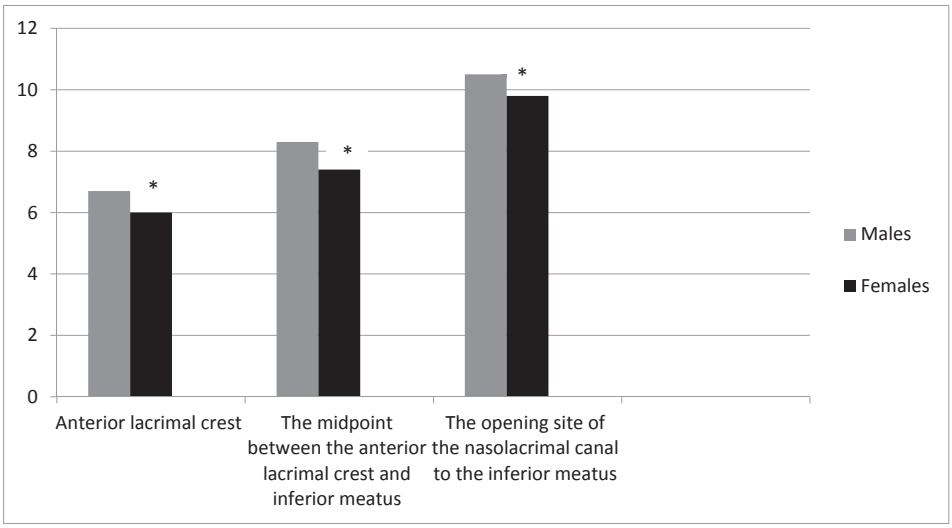

Fig. 8. Comparison of distances to the lateral osteotomy line between females and males on the left side; $^{*}p < 0.05$.

In a retrospective study conducted with 500 patients who had undergone aesthetic rhinoplasty, Sachs determined that epiphora had developed in 12 patients in the early postoperative period; the epiphora did not continue beyond 6 months in any of the patients. He also reported that lacrimal system injury would more likely occur during creation of a subperiosteal tunnel in the lateral nasal wall or while performing the lateral osteotomy using a saw. This was attributed to the structure of the medial canthal tendon being undermined, and linked to a risk of injury to the 10–11-mm-long lacrimal sac, since its protection by the bone was disrupted. Sachs suggested that by using a tiny osteotome — 4 mm in length — and without creating a subperiosteal tunnel, the risk of lacrimal system injury would be less (Sachs, 1984).

In our study, the lateral osteotomy line was planned to pass tangentially to the anterior of the medial canthal ligament. Since no medial canthal ligament was injured in any of the 80 patients (40 females, 40 males), we suggest that, using this approach and based on our study, the lacrimal sac is preserved and no lacrimal system injury will occur.

Yiğit et al. conducted a study on 20 patients (11 females, 9 males) related to the evaluation of lacrimal system injury by performing dacryocystography, together with measurements on 4 mm axial CT sections in the 6th–7th postoperative month. They found that the distance from the lacrimal fossa to the osteotomy line was 8.1 ± 2.3 mm (range 3–11 mm) on the right side and 8.0 ± 2.4 mm (range 3–11 mm) on the left side, and reported that no lacrimal system injury was present (Yigit et al., 2004).

In our study, the thickness of the axial sections was 0.6 mm. The safety margin between the lateral osteotomy line and the anterior lacrimal crest had a mean of 6.0 mm (range 4.5–7.5 mm) on the right side and 6.0 mm (range 4.5–7.4 mm) on the left side in females, and 6.7 mm (range 5.0–8.4 mm) on the right side and 6.7 mm (range 5.0–8.4 mm) on the left side in males. A standard deviation of 0.8 mm in both the females and males showed that the differences between the maximum and minimum values were small. The significant differences found between females and males in our study suggest that the safe osteotomy line is within narrower

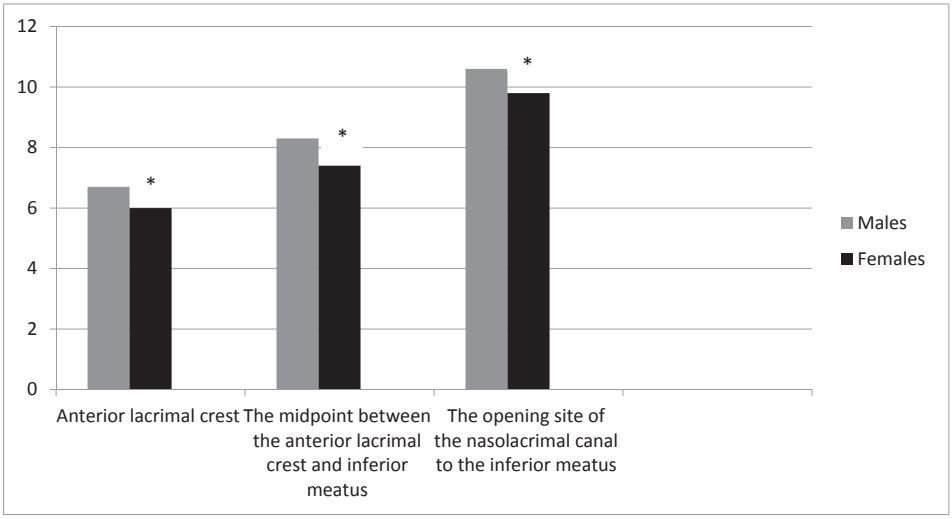

Fig. 9. Comparison of distances to the lateral osteotomy line between females and males on the right side; $^{*}p < 0.05$.

limits in females when compared with males. This might suggest that, when the procedure is not performed carefully (also taking racial differences into consideration), the rate of epiphora complications may be increased in females.

In their study, Moscatiello et al. divided 210 patients who were to undergo rhinoplasty operations into three groups. For preoperative evaluation and planning they used the patients' clinical appearance and photograph in the first group, Adobe Photoshop in the second group, and three-dimensional CT images in the third group. When they evaluated the postoperative functional and aesthetic results of the patients, they determined that revision requests were less and functional results of assessment with rhinomanometry were better in patients for whom three-dimensional CT was used in the preoperative evaluation. They also stated that the patients understood the information given to them in the preoperative period about the operative procedure and its potential complications (Moscatiello et al., 2010). This study supports the results of our study.

5. Conclusion

In conclusion, we recommend three-dimensional CT for preoperative evaluation and planning because this will make the operative procedure easier to perform. Although the eye of the surgeon combined with use of the index finger is the routine way to decide the osteotomy line in rhinoplasty, use of three-dimensional CT analysis may be necessary in some cases. Challenging cases and revision rhinoplasties may require a more detailed preoperative assessment. Three-dimensional CT analysis can be helpful in preventing complications such as lacrimal system injury. We think that performing the lateral osteotomy meticulously and paying attention to remaining anterior to the medial canthal ligament will not lead to any lacrimal system injury. Our suggestions need to be supported by future clinical studies.

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