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RESEARCH ARTICLE

Computed tomographic assessment of the lacrimal sac fossa in the Japanese population☆

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ABSTRACT

Purpose: To analyze the morphology of the lacrimal sac fossa in the Japanese population using computed tomographic images.
Materials and methods: One-hundred-fifty-five Japanese patients diagnosed with unilateral orbital fracture were retrospectively reviewed. Measurements of the dimensions of the lacrimal sac fossa were taken on three anatomical planes (upper, middle, and lower planes) using a digital caliper/protractor tool.
Results: The mean maximum thickness of the maxillary bone at the upper, middle, and lower planes of the lacrimal sac fossa were 4.60 mm, 5.07 mm, and 6.30 mm, respectively. The midpoint thickness of the maxillary bone at each plane were 3.04 mm, 3.00 mm, and 2.17 mm, respectively. The lacrimal bone thickness at each plane were 1.13 mm, 1.13 mm, and 1.08 mm, respectively. The proportion of the lacrimal sac fossa comprising of the lacrimal bone at each plane were 39.00%, 42.05%, 38.92%, respectively. On the middle plane, the mean angle between the lacrimal bone and sagittal plane was 131.92°.
Conclusions: In Japanese patients, the proportion of the lacrimal bone on the lacrimal sac fossa tended to be of greater proportion compared to studies done on other races. The mean angle of the lacrimal sac fossa seemed to be comparatively high. These results indicate that performing an osteotomy during dacryocystorhinostomy could be relatively easier in the Japanese population compared to other races.

1. Introduction

The lacrimal sac fossa is a depression in the inferomedial aspect of the orbital rim, comprising of a thick maxillary bone and a thin lacrimal bone in variable proportions (Bisaria et al., 1989; Hartikainen et al., 1996; Shams et al., 2012; Valencia et al., 2019). This variation is in relation to the position of the lacrimo-maxillary suture, which represents the junction between the two bones and is located between the anterior and posterior lacrimal crest (Shams et al., 2012). During dacryocystorhinostomy (DCR), a bone window is created at the lacrimal sac fossa to create a bypass from the lacrimal sac to the nasal cavity. Variations in morphology of this area affect the ease or difficulty of performing a DCR in each case.

Various studies have been published showing this variability in the lacrimal sac fossa morphology among the different racial groups. Overall, the lacrimal bone ratio of the lacrimal sac fossa seems to be higher in Indians, compared to the Caucasians, black African, or Koreans, and the maxillary bone has been found to be thinner in the Caucasians than either the black African or Korean population (Bisaria et al., 1989; Hartikainen et al., 1996; Woo et al., 2011; Agarwal and Kumar, 2012; Shams et al., 2012; Yong et al., 2014; Gore et al., 2015; Kang et al., 2017). The aim of this study is to assess the morphology of the lacrimal sac fossa using computed tomographic (CT) images in the Japanese population.

2. Materials and methods

This retrospective observational study was approved by the Institutional Review Board (IRB) of Aichi Medical University Hospital and has adhered to the tenets of the 1964 Declaration of Helsinki. The IRB granted a waiver of informed consent for this study based on the ethical guidelines for medical and health research involving human subjects established by the Japanese Ministry of Education,

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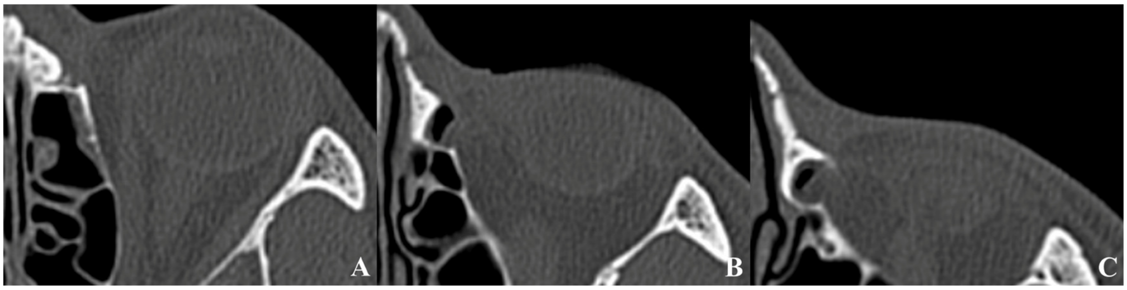

Fig. 1. The upper (**A**), middle (**B**), and lower axial planes (**C**).

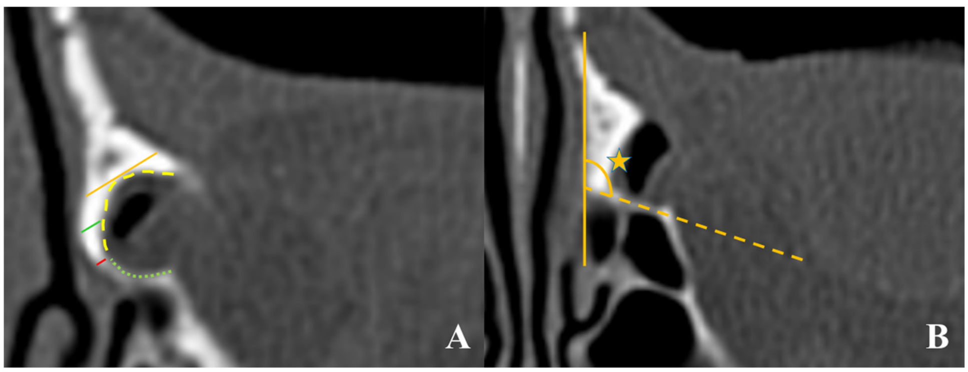

Fig. 2. Measurements of the dimensions of the lacrimal fossa.
A. The thickness and length of the maxillary and lacrimal bones on the lower plane. At 30° from the coronal plane, the maximum (orange line) and midpoint thickness of the maxillary bone (green line), and the thickness of the lacrimal bone near the lacrimo-maxillary suture (red line) were measured. The length of the maxillary (yellow broken line) and lacrimal bone in the lacrimal fossa (green dotted line) was also measured.
B. The angle between the lacrimal bone (broken line) and sagittal plane (solid line) on the middle plane was measured (asterisk). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Culture, Sports, Science, and Technology, and by the Ministry of Health, Labor, and Welfare. The waiver was granted since the study was a retrospective chart review, and not an interventional study. Furthermore, it would be difficult to obtain consent from patients who have been treated several years prior. Nevertheless, at the request of the IRB, we published an outline of the study that was available for public viewing on the Aichi Medical University website. This also provided patients the opportunity to withdraw from participation. However, none of the patients declined to participate. Personal identifiers were removed from the records prior to data analysis.

This study was a retrospective chart review of all Japanese patients diagnosed with an orbital fracture between February 2017 and November 2018. Patients with unilateral blowout fracture who had axial CT scans taken with the thickness of 2 mm or less were included in this study. Only the unaffected sides were included in this study. On the other hand, patients with bilateral blowout fracture or multiple facial fractures were excluded from this study. Likewise, patients with a history of orbital, lacrimal, or paranasal sinus surgery on the unaffected side were excluded. Finally, patients who had axial CT scans with the thickness of >2 mm were also excluded from this study.

Contiguous 0.6–2.0 mm axial CT images (Aquillion 64; Toshiba, Tokyo, Japan) were obtained using a bone window algorithm (width: 2500; level: 500). The measurement protocol was made in reference to a previous study by Gore et al. (2015) (Figs. 1 and 2). The first axial plane below the fronto-lacrimo-maxillary suture showing the concavity of the lacrimal sac fossa was identified as the "upper plane" (Fig. 1A). The "lower plane" was the last axial plane before the appearance of the complete ring of the nasolacrimal canal entrance (Fig. 1C). The middle plane was chosen as the cut midway between the upper and lower planes (Fig. 1B).

All measurements were performed using the digital caliper/protractor tool of the viewing software (ShadeQuest/ViewR; Yokogawa Medical Solutions Corporation, Tokyo, Japan) by one of the authors (YT). After maximum magnification of the images, the dimensions of the lacrimal sac fossa were measured on the three planes. The maximum thickness of the maxillary bone, which is the midpoint thickness of the maxillary bone at a site halfway between the maximum line and lacrimo-maxillary suture, as well as the thickness of the lacrimal bone just posterior to the lacrimo-maxillary suture were measured at 30° from the coronal plane (Fig. 2A). The length of the maxillary and lacrimal bone in the lacrimal sac fossa was also measured using a digital freehand caliper (Fig. 2A). The proportion of the length of the lacrimal bone with respect to the total length of the lacrimal sac fossa was calculated as follows: length of the lacrimal bone/total length of the lacrimal sac fossa ×100. The angle between the lacrimal bone and sagittal plane was also measured at the level of the middle plane (Fig. 2B). Since the anterior lacrimal crest in children is poorly defined and the lacrimal sac fossa tends to be shallow, we kept in mind during CT measurements that the anterior lacrimal crest is contiguous with the inferior orbital margin (Katowitz et al., 2018). We also examined an anatomical variation of lacrimal sac within the ethmoid sinus (Ali et al., 2016).

Patient age and measurements obtained were expressed as means ± standard deviations. Patient age, thickness, proportion, and angle were compared between sexes using the Student's t-test. Correlation between the thickness and patient age was analyzed using Pearson's correlation coefficient. Multivariate linear regression analysis with stepwise variable selection was performed to identify factors influencing the proportion and angle, such as patient age, thickness, and length. These statistical analyses were

Table 1
Results of measurements and sex-related differences.

	Upper	Middle	Lower
Maximum thickness (mm)			
Total	4.60 ± 1.14	5.07 ± 1.11	6.30 ± 1.33
Males	4.59 ± 1.12	5.08 ± 1.07	6.41 ± 1.36
Females	4.64 ± 1.15	5.07 ± 1.19	6.12 ± 1.25
P values	0.758	0.966	0.177
Midpoint thickness (mm)			
Total	3.04 ± 0.88	3.00 ± 0.83	2.17 ± 0.66
Males	3.10 ± 0.89	3.03 ± 0.84	2.18 ± 0.69
Females	2.94 ± 0.82	2.97 ± 0.82	2.17 ± 0.60
P values	0.277	0.667	0.933
Lacrimal bone thickness (mm)			
Total	1.13 ± 0.28	1.13 ± 0.27	1.08 ± 0.29
Males	1.13 ± 0.27	1.13 ± 0.27	1.05 ± 0.28
Females	1.15 ± 0.31	1.14 ± 0.28	1.13 ± 0.30
P values	0.677	0.769	0.132
Proportion of lacrimal fossa comprising lacrimal bone (%)			
Total	39.00 ± 11.31	42.05 ± 10.00	38.92 ± 8.33
Males	38.59 ± 10.23	41.97 ± 9.77	39.67 ± 7.89
Females	39.67 ± 12.96	42.28 ± 10.77	38.13 ± 8.84
P values	0.567	0.854	0.264
Angle (degrees)			
Total		131.92 ± 14.94	
Males		131.69 ± 15.33	
Females		132.00 ± 14.25	
P value		0.902	

Table 2
Correlation between patient age and thickness on each plane.

	Correlation coefficient	P values
Maximum thickness		
Upper	0.324	<0.001
Middle	0.226	0.005
Lower	0.279	<0.001
Midpoint thickness		
Upper	0.163	0.043
Middle	0.084	0.296
Lower	0.067	0.409
Lacrimal bone thickness		
Upper	0.240	0.003
Middle	0.170	0.034
Lower	0.257	0.001

performed using SPSS™ version 22 software (IBM Japan, Tokyo, Japan). A P value of <0.05 was considered statistically significant.

3. Results

Results of measurements and statistical analyses are shown in Tables 1–4. One-hundred-fifty-five sides from 155 patients (81 right and 74 left; 98 men and 57 women; age, 40.6 ± 23.2 years; range: 3–91 years) were included in this study. Although the males (37.7 ± 21.8 years) tended to be younger than the females (44.6 ± 25.1 years) included in this study, the difference did not reach statistical significance ($P = 0.078$).

The maximum thickness of the maxillary bone increased from the upper to the lower plane. In contrast, the midpoint thickness decreased from the upper to the lower plane. The lacrimal bone thickness was almost uniform throughout the fossa. The thickness and proportion on each plane and the angle did not show sex-related difference ($P > 0.050$). For all 3 planes, the maximum thickness and the lacrimal bone thickness had a weak positive correlation with age ($P < 0.050$). Likewise, the midpoint thickness on the upper plane had a weak positive correlation with age ($P = 0.043$).

The middle plane showed the greater proportion of the lacrimal bone in the lacrimal sac fossa in comparison to the upper and lower planes. Using a stepwise process, all items were removed from the regression model for the proportion on the upper plane ($P > 0.050$). Predictors for the proportion on each plane were as follows: patient age at the level of the middle plane (adjusted $r^2 = 0.023$; $P = 0.033$) and patient age and maximum thickness at the level of the lower plane (adjusted $r^2 = 0.089$; $P < 0.001$). However, the correlation was very weak.

On the middle plane, the mean angle between the lacrimal bone and sagittal plane was 131.92°. The midpoint thickness, maxillary and lacrimal bone length were predictors for the angle. But again, the correlation was very weak (adjusted $r^2 = 0.112$; $P < 0.001$).

None of the patients showed the anatomical variation of a lacrimal sac entirely within the ethmoid sinus.

4. Discussion

In this study, we have measured the proportion, thickness, and angle of the maxillary and lacrimal bone on the lacrimal sac fossa of Japanese patients. To our knowledge, this is the first time that such a study has been undertaken in this demographic.

A good osteotomy is a pre-requisite for DCR (Tao et al., 2014; Yong et al., 2014). A higher ratio of the lacrimal bones per total length of the lacrimal sac fossa can result in an easier osteotomy creation during DCR since a thin lacrimal bone can easily be fractured (Yung and Logan, 1999; Ricardo et al., 2010; Raikos et al., 2015). The approach to achieving an adequate osteotomy by cleavage of the maxillary and lacrimal bones differs between external and endonasal DCRs due to the various surgical orientation (Fayet et al., 2005). Therefore, a thorough understanding of the anatomical variation of the lacrimal sac fossa is crucial in preparing the surgeon for an appropriate surgical approach during DCR (Yong et al., 2014; Kang et al., 2017).

In our study, the maxillary bone on an average showed an increased thickness from upper to the lower plane with an average maximum thickness of 4.60 mm on the upper plane and 6.30 mm on the lowermost plane. On the contrary, the midpoint thickness

Table 3
Influence of patient age and thickness on the proportion of the lacrimal fossa comprising the lacrimal bone.

	Upper		Middle		Lower	
	P values	Unstandardized coefficient (95% confidence interval)	P values	Unstandardized coefficient (95% confidence interval)	P values	Unstandardized coefficient (95% confidence interval)
Age	–	–	0.033	−0.075 (−0.143 to −0.006)	< 0.001	−0.098 (−0.152 to −0.044)
Maximum thickness	–	–		–	0.022	2.255 (0.337–4.172)
Midpoint thickness	–	–		–	–	–
Lacrimal bone thickness	–	–		–	–	–

Table 4
Influence of patient age, thickness, and length on the angle between the maxillary and lacrimal bones.

	P value	Unstandardized coefficient (95% confidence interval)
Age	–	–
Maximum thickness	–	–
Midpoint thickness	0.008	−3.669 (−6.377 to −0.961)
Lacrimal bone thickness	–	–
Maxillary bone length	0.036	−1.553 (−3.004 to −0.103)
Lacrimal bone length	0.003	2.788 (0.985–4.592)

was greater on the upper plane with an average measurement of 3.04 mm. The lacrimal bone thickness was almost uniform throughout the fossa with a maximum measurement of 1.13 mm on the upper and middle plane, and 1.08 mm on the lowermost plane. It was also noted that on an average, the middle plane (42.05%) accounted for the greater proportion of lacrimal bone on the fossa in comparison to the upper (39.00%) and lower (38.92%) planes.

Our results contrast with those in the study done on black Africans and Caucasians by Gore et al. (2015). The proportion of lacrimal bone of both races in that previous study was less in almost all the planes compared to the Japanese population in our study. However, the exception was the lowermost plane in Caucasians, which was found to be slightly higher than ours (black Africans: upper, 36.3%; middle, 27.9%; lower, 34.3%. Caucasians: upper, 37.5%; middle, 36.5%; lower, 39.6%) (Gore et al., 2015).

With regard to maximum maxillary thickness, black Africans had higher values on all planes (upper, 5.6 mm; middle, 5.2 mm; lower 8.5 mm) while Caucasians had less in the upper and middle planes (upper, 3.6 mm; middle 4.0 mm; lower 6.6 mm) (Gore et al., 2015). On the contrary, our study showed thicker midpoint measurement than both races, except for the upper plane, in black Africans (black Africans: upper, 3.1 mm; middle, 2.0 mm; lower, 1.2 mm. Caucasians: upper, 2.0 mm; middle, 1.5 mm; lower, 1.3 mm) (Gore et al., 2015).

Other studies on Caucasians have shown that the lacrimomaxillary line almost bisected the lacrimal sac fossa sagittally (Chastain et al., 2005; Shams et al., 2012). In Indian studies, it was reported that 46.06–79.17% of the total orbits studied showed the proportion of lacrimal and maxillary bone in the lacrimal sac fossa to be 50% (Bisaria et al., 1989; Agarwal and Kumar, 2012). These results indicate a higher proportion of lacrimal bone percentage compared to our study. However, the calculations in those studies have been based on an overall average in relation to the entire fossa rather than specific anatomical areas (Bisaria et al., 1989; Chastain et al., 2005; Agarwal and Kumar, 2012; Shams et al., 2012).

Studies done on other East Asian populations have also shown contrasting results to our study. In the study by Woo et al. (2011), the midpoint thickness was found to be thinner in the middle and lower planes (upper, 3.3 mm; middle, 2.6 mm; lower, 2.0 mm), compared to the Japanese population in our study. The study by Kang et al. (2017) also demonstrated a thinner maxillary bone at the midpoint in the upper and middle planes (upper, 2.42 mm; middle 2.56 mm; lower, 2.18 mm). Therefore, it is important to point out that there are dissimilarities even in the East Asian population. The lacrimal bone proportion was significantly less in the study done by Woo et al. (2011) (upper, 21.0%; middle, 31.0%; lower, 37.6%). However, our study almost had similar findings with that of Kang et al. (2017) (upper, 39%; middle 39%; lower, 43%).

The study by Gore et al. (2015) demonstrated an apparently thinner lacrimal bone compared to our study (black African, 0.09–0.12 mm; Caucasians, 0.09–0.10 mm). A previous UK study using cadavers of undisclosed races showed a much thinner lacrimal bone (mean, 0.057 mm) (Yung and Logan, 1999). Setting aside the anatomic racial differences, we cannot exclude the possibility that the reported differences in measurement results between the studies may have been caused by various measurement methods and tools.

In this study, we measured the angle between the lacrimal bone and sagittal plane, which had not been previously done. The lacrimal bone is first punched using the tip of the Kerrison rongeur or an elevator during creation of a bone window in external DCR (Olver, 2002). However, in patients with a lacrimal bone angle of 90°, the initial punch is often difficult. However, it is quite easy to perform an osteotomy on such a patient using a Kerrison rongeur during endonasal DCR (Chong, 2015). The lacrimal sac fossa with the mean angle of approximately 130° in our study may be easily removed during both external and endonasal DCRs.

This study was carried out in both pediatric and late-adulthood patients (3–91 years) because DCR is commonly indicated in middle-to-late adulthood patients but is also done in the pediatric population (Bothra et al., 2018; Dave et al., 2018). The maximum thickness on all three planes, the midpoint thickness on the upper plane, and the lacrimal bone thickness on all three planes showed some positive correlation to age. In addition, the proportion of the lacrimal bone length with respect to the total length of the lacrimal sac fossa was found to be negatively correlated with age. These could mean more difficulty in performing DCR in elderly than younger patients.

On the whole, the maxillary bone was thicker in Japanese, compared to the other races cited in this study. However, due to the relatively larger proportion of lacrimal bone constituting the lacrimal sac fossa in Japanese, we can, with some degree of certainty, say that performing osteotomy could be relatively easier in the Japanese population compared to other races. In addition, a bone window can easily be created in the lacrimal sac fossa with the mean angle of approximately 130° during both external and endonasal DCRs.

This study has several limitations. First, the study design was retrospective. Second, the thickness of CT scans varied in each case. Third, we could not directly compare our results with those studied in other races using statistical methods. Fourth, the data were derived from the unaffected side of post-orbital fracture cases. Although extremely rare, there could be a minimal risk of an anatomical change occurring on the contralateral side as a result of the orbital fracture, thereby providing a variation in our results.

5. Conclusion

The bony anatomy of the lacrimal sac fossa varies according to race. Our study assessed the bony constituents of the lacrimal sac fossa in the Japanese population. Our results show that maximal lacrimal to maxillary bone ratio and a higher mean angle of lacrimal sac fossa are both found in the Japanese population. These results indicate that performing an osteotomy during dacryocystorhinostomy could be relatively easier in the Japanese population compared to other races.

Informed consent

This retrospective observational study was approved by the Institutional Review Board (IRB) of Aichi Medical University Hospital and has adhered to the tenets of the 1964 Declaration of Helsinki. The IRB granted a waiver of informed consent for this study based on the ethical guidelines for medical and health research involving human subjects established by the Japanese Ministry of Education, Culture, Sports, Science, and Technology, and by the Ministry of Health, Labor, and Welfare. The waiver was granted since the study was a retrospective chart review, and not an interventional study. Furthermore, it would be difficult to obtain consent from patients who have been treated several years prior. Nevertheless, at the request of the IRB, we published an outline of the study that was available for public viewing on the Aichi Medical University website. This also provided patients the opportunity to decline from participation. However, none of the patients declined to participate. Personal identifiers were removed from the records prior to data analysis.

Originality and plagiarism

The authors ensure that they have written entirely original works, and if the authors have used the work and/or words of others, that this has been appropriately cited or quoted.

Multiple, redundant or concurrent publication

This article has not been submitted for publication nor has it been published in whole elsewhere.

Contributors

No one contributed to the work who did not meet our authorship criteria.

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