Analysis of Orbital Morphology and its Relationship With Eyelid Morphology

Osaki, Takeo ; Murakami, Hidetaka ; Tamura, Ryosuke ; Nomura, Tadashi ; Hashikawa, Kazunobu ; Terashi, Hiroto

(Citation)
Journal of Craniofacial Surgery,31(7):1875-1878

(Issue Date)
2020-10

(Resource Type)
journal article

(Version)
Version of Record

OPEN

Analysis of Orbital Morphology and its Relationship With Eyelid Morphology

Takeo Osaki, MD, Hidetaka Murakami, MD,† Ryosuke Tamura, MD,* Tadashi Nomura, MD, PhD,* Kazunobu Hashikawa, MD, PhD,* and Hiroto Terashi, MD, PhD**

Abstract: Correct anatomical reconstruction of the orbital wall for function and cosmesis is important; however, this is difficult because of the structure's complexity. The authors aimed to analyze and classify orbital morphology from computed tomography (CT) images and examine the relationship between orbital morphology and eyelid morphology in the Japanese population. CT images of 60 men (right side, 29; left side, 31) and 44 women (each side, 22) were included. The lengths of the orbital medial wall and floor in the coronal plane at the anterior, middle, and posterior planes of the orbit; angle between them; simotic index; and the thickness of upper eyelid were measured. Additionally, the presence or absence of double eyelids was evaluated. Non-paired Student's *t* test and Pearson correlation coefficient test were used for analysis. Orbital morphology was symmetrical on both sides, and men had a larger orbit than women. Orbital morphology was classified into 2 groups according to the posterior angle, and there was a difference between the groups in the simotic index. The difference between groups may represent a genetic difference between the Jomon and Yayoi people and not only provide a new classification for the orbit of the population but also be useful in orbital reconstruction.

Key Words: Blowout fracture, double eyelids, orbit, orbital morphology

(*J Craniofac Surg* 2020;31: 1875–1878)

In orbital blowout fractures and tumor resection around the orbit, it is often necessary to reconstruct the orbital wall using autogenous bone, a titanium mesh, or absorbable sheet.[1–3] However, it is difficult to reconstruct the orbital wall extensively from the medial wall to the orbital floor and retain its original shape because of its complicated anatomical structure. The structure of the orbital wall is complex because the lengths of the medial wall and orbital floor and the angle formed by them differ between the front and the rear. Analyzing and standardizing or classifying these angles and lengths is considered to have extremely high clinical significance. Additionally, if orbital morphology is classified, it can be associated with facial features. The presence or absence of double eyelid formation is an important factor in the appearance of the eyelid in the Japanese population. If the orbital morphology can be inferred from the characteristics of the double eyelid, it is considered clinically significant. This study aimed to analyze and classify the orbital morphology from computed tomography (CT) images, and to examine the relationship between orbital morphology and eyelid morphology in the Japanese population.

MATERIALS AND METHODS

Ethical Approval

This study was conducted in accordance with the Declaration of Helsinki. Due to the retrospective, non-interventional nature of the study, tacit consent was applied, and participants were able to opt-out of the study via our website. The study protocol was reviewed and approved by an ethics committee (authorization number B190160).

Study Subjects

From April 2016 to June 2019, facial CT was performed, and patients for whom we were able to obtain multiplanar reconstruction images from the remaining image data were targeted. Patients with damaged or missing orbital bones on both sides and those judged not to be Japanese were excluded.

Measurements and Imaging

The lengths of the orbital medial wall and floor in the coronal plane at the anterior, middle, and posterior planes of the orbit and the angle between them were measured. The coronal plane was set as the plane perpendicular to the palatal plane; the anterior plane was the coronal plane that passes through the posterior lacrimal crest; the middle plane passed through the outermost inferior orbital fissure; and the posterior plane passed through the posterior ethmoidal foramen (Fig. 1).

The height of the nasal bone was evaluated using the simotic index, which is used as an index to evaluate facial flatness.[4,5] The simotic index is usually measured at the narrowest part of the nasal bone, but to ensure accuracy of the measurement on CT images, it was measured at the attachment point of the perpendicular plate of the ethmoid bone in this study (Fig. 2). CT images were measured using a 3-dimensional (3D) CT image processing workstation (ziostation2; Ziosoft, Tokyo, Japan).

The thickness of the upper eyelid was also measured from CT images. According to the method measured by Shimbo et al,[6] the thickness of the upper eyelid was measured at the midpoint of the upper orbital margin and the lid margin at the center of the eyeball

From the *Department of Plastic Surgery, Kobe University Graduate School of Medicine; and †Kawasaki Hospital, Kobe, Japan.

Received January 29, 2020.
Accepted for publication March 30, 2020.

Address correspondence and reprint requests to Takeo Osaki, MD, Department of Plastic Surgery, Kobe University Graduate School of Medicine, 7-5-1 Kusunoki-chou, Chuo-ku, Kobe 650-0017, Japan; E-mail: yellowcox@yahoo.co.jp

The authors have no conflicts of interest to disclose.
Supplemental digital contents are available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jcraniofacialsurgery.com).

ISSN: 1049-2275
DOI: 10.1097/SCS.0000000000006634

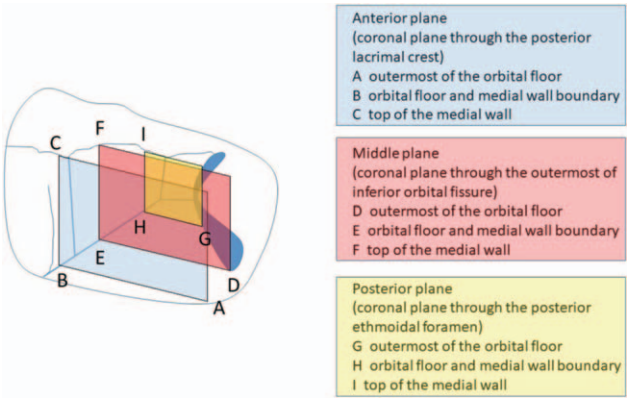

FIGURE 1. Measured point (definition of the coronal planes).

with the eyes closed in a sagittal cross-sectional image (Fig. 3). Several cases that had only a CT image at the time of eyelid opening were excluded from the measurement.

For those whose facial photographs were taken, the presence or absence of double eyelids was evaluated. At that time, those who were undergoing surgery for double eyelid formation were excluded.

Statistical Analysis

Since all these parameters showed a normal distribution or were regarded as having a normal distribution, comparisons were performed using the non-paired Student's *t* test. Correlations were analyzed using Pearson correlation coefficient test. The Microsoft Excel package (Microsoft, Redmond, WA) was used to perform the statistical analyses. A P value < 0.05 was considered statistically significant.

RESULTS

Demographics

Computed tomography images of 60 men (right side, 29; left side, 31) and 44 women (both sides, 22) were included in the study. There was no significant difference in age between men and women (Supplementary Digital Content, Table 1, http://links.lww.com/SCS/B461).

Differences in Laterality and Sex

In both sexes, the length and angle of the orbital medial wall and floor were similar to each other in the anterior, middle, and posterior planes (Supplementary Digital Content, Table 2, http://links.lww.com/SCS/B461).

The orbital floor length in the anterior and middle planes (23.81 ± 2.11 versus 22.01 ± 1.81 and 20.58 ± 1.96 versus 19.32 ± 1.82 mm, respectively, $P < 0.01$) and medial wall length in the posterior plane (11.18 ± 2.17 versus 10.1 ± 1.55 mm, $P < 0.01$) were significantly larger in men than in women. The simotic index was also higher for men than for women (0.67 ± 0.14 versus 0.54 ± 0.12, $P < 0.01$) and the thickness of upper eyelid tended to be greater in men than in women, but this difference was not significant (3.75 ± 0.79 versus 3.44 ± 0.79, $P = 0.06$). The angles were not different between sexes in any plane (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/B461).

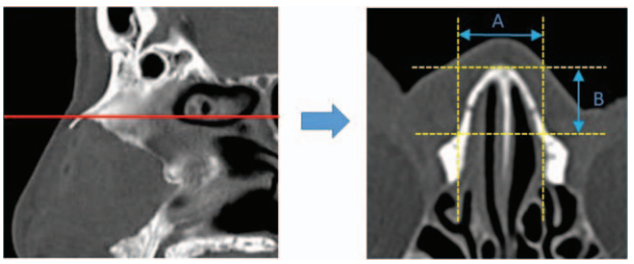

FIGURE 2. Simotic Index = B/A. A: the simotic chord (the minimum horizontal breadth of the nasal bone) B: simotic subtense (the minimum distance from the midian ridge of the nasal bone to the simotic chord).

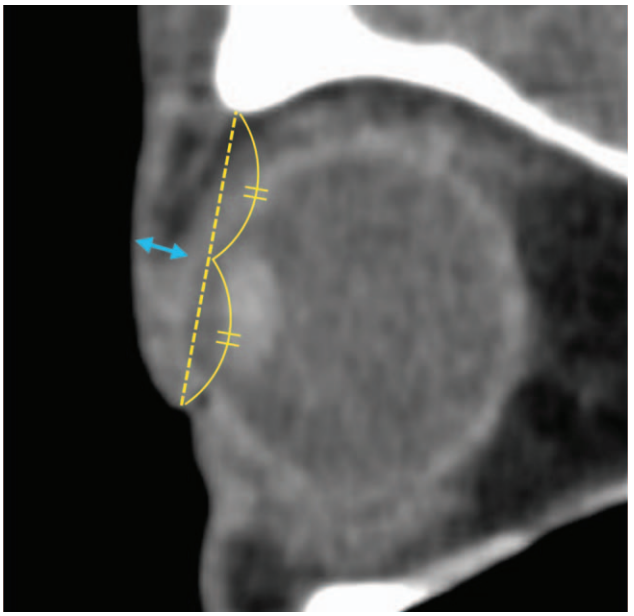

FIGURE 3. Thickness of upper eyelid.

Correlation Between Angle and Length

In both sexes, a negative correlation was observed between the angle and orbital medial wall and floor-length in the anterior plane (ie, the larger the angle, the shorter the length). In the middle plane, there was a negative correlation between the angle and orbital medial wall length in men, and between the angle and orbital floor-length in women. In the posterior plane, there was a negative correlation between the angle and orbital floor-length in women (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/B461).

Classification and Comparison of Orbital Morphologies

On average, the angle between the orbital medial wall and floor increased backwards in both sexes. However, from the middle plane to the posterior plane, the angle was classified into 2 groups: type A, reduced angle, and type B, increased angle (Fig. 4). There were 28 cases of type A and 32 cases of type B in men, and 9 cases of type A and 35 cases of type B in women.

There was no difference in the length of the orbital medial wall and floor between the type A and type B group. Compared to the angle in type A, that in type B was significantly larger in the posterior plane, but this was a natural result because the groups were divided according to the angle. The simotic index was significantly higher in type A than in type B for both sexes (0.72 ± 0.15 versus 0.62 ± 0.11, $P < 0.01$ and 0.63 ± 0.18 versus 0.52 ± 0.09, $P = 0.015$). The average thickness of upper eyelid was larger in type B than in type A for both sexes, and this difference was

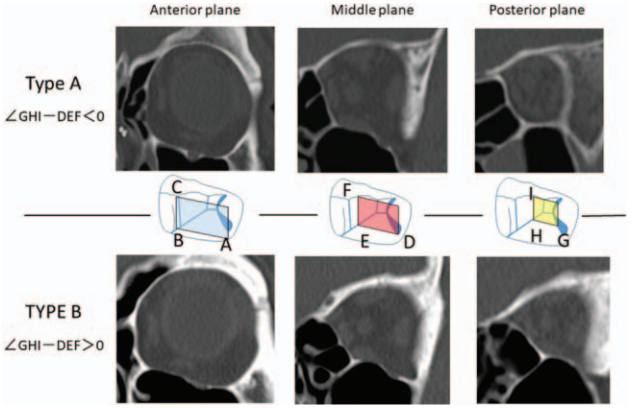

FIGURE 4. Classification of orbital morphology.

significant in women (2.85 ± 0.65 versus 3.57 ± 0.77, $P = 0.018$) (Supplementary Digital Content, Table 5, http://links.lww.com/SCS/B461).

Correlation Between the Classification of Orbital Morphology and Presence of Double Eyelids

We were able to evaluate the faces of 19 men in the type A group and 18 men in the type B group. In type A, 74% (14 people) had double eyelids, and in type B, 56% (10 people) had double eyelids. We were able to evaluate the faces of 5 women in the type A group and 21 women in the type B group. In type A, 60% (3 people) had double eyelids, and in type B, 43% (9 people) had double eyelids. In both sexes, the type A group had a higher percentage of individuals with double eyelids than the type B group, but no significant difference was observed (Fig. 5).

Correlation Between the Thickness of Upper Eyelid and Presence of Double Eyelids

For both men and women, the average thickness of upper eyelid was larger for people who did not have double eyelids, and this difference was significant in men (3.34 ± 0.62 versus 4.00 ± 0.54, $P < 0.01$) (Supplementary Digital Content, Table 6, http://links.lww.com/SCS/B461).

DISCUSSION

Reconstruction of the orbital wall using a 3D model is considered the best way to reconstruct the complex orbital morphology, and there are many reports of using such a method.[7–12] However, the creation of 3D models has some disadvantages; for example, it requires specific equipment and cannot be used for emergency surgery because of the time required to create the model. If 3D models are not available, knowing the general morphology of the orbit will be of great assistance in reconstructive surgery. This study started with that perspective in mind.

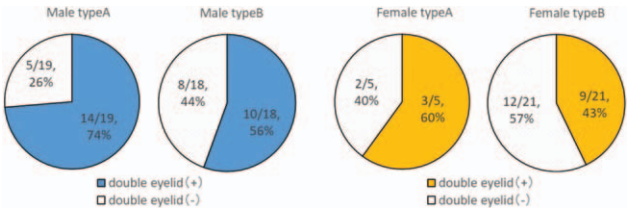

FIGURE 5. Classification of orbital morphology.

There have been several reports on the analysis of normal orbital morphology using CT images.[13–18] Nagasao et al found that inclination of the orbital floor was steeper in children than in adults and steeper in men than in women; additionally, the lowest point of the orbital floor shifted lower and more posteriorly with age.[13] Hasan reported that the left and right orbits are symmetrical and that the orbital size is smaller in women than in men.[16] Similarly, Fitzhugh et al reported that the orbit is generally not different in laterality between sexes but that in men it is larger.[18] Our study also showed that the left and right sides are symmetrical between sexes and that men have larger orbits than women do.

An attempt to create a template by standardizing the shape of the orbit using statistical shape analysis has also been reported.[19] Although it is useful because the orbital morphology can be reconstructed with a certain degree of accuracy without creating a 3D model, it is difficult to obtain good results if the orbital morphology varies greatly from individual to individual. In our study, there were groups in which the angle between the orbital medial wall and floor was reduced (type A) or increased (type B) from the middle plane to the posterior plane. This finding suggests that orbital morphology is diverse and difficult to standardize. Interestingly, the type A group had a significantly higher simotic index than the type B group, and there was a tendency for many people to have double eyelids.

According to anthropological studies, Japanese individuals are genetically divided into Jomon people, the first migrants from southeast Asia, and Yayoi people from Northeast Asia.[20–23] Jomon people have features of wide eyes and visible superior palpebral creases (double eyelid), whereas Yayoi people have narrow eyes for cold tolerance and no visible superior palpebral crease (no double eyelids).[24] Additionally, Jomon people have a 3D face,[25,26] and there are reports that the simotic index is larger in Jomon people than in Yayoi people.[27] Therefore, the different orbital morphology (type A and type B) in our study may represent the difference between Jomon people and Yayoi people. Moreover, in Eastern Eurasia, anatomically modern humans are divided into 2 layers by craniometrics. Jomon people belong to the first layer and are likely to have migrated into this region via the Southeast Asian landmass prior to 65–50 kya, Yayoi people belong to the second layer and had likely dispersed from areas in Northeast Asia such as Siberia after 9 kya.[28] The differences that we have found in this study may be due to these layer differences that are observed in East and Southeast Asia.

In this study, the relationship between orbital morphology and double eyelids could not be directly shown. However, people with type B orbital morphology tended to have thicker eyelids than people with type A. On the other hand, people without double eyelids tended to have thicker eyelids than those with double eyelids. Eyelid thickness is an important factor for Asians, and thinness and pliability are considered vital for double eyelids.[29–31] The above results are thought to indirectly indicate the mechanism between orbital morphology and double eyelids.

There are limitations to this research study. First, since the number of people who had photographs of their eyelid morphology was limited, the number of people who underwent evaluation of their eyelids was small. Second, the formation of the eyelid changes because aging causes eyelid sagging. From that viewpoint, the comparison of the presence or absence of double eyelids requires adjustment by age, but this was not done in this study.

In future studies, the validity of the classification of the orbital morphology obtained in this study and the results related to the eyelid morphology may be supported by further increasing the number of cases. Studies may also consider whether orbital

morphology classification is related to fracture prone sites (medial wall or floor etc.) in orbital fractures.

CONCLUSIONS

We found that orbital morphology was symmetrical on both sides in both sexes and that men had a larger orbital shape than women. We also found that there were groups in which the angle between the orbital medial wall and floor was reduced or increased from the middle plane to the posterior plane. In addition to the complexity and diversity of the orbital morphology shown, these differences may represent genetic differences between Jomon people and Yayoi people. We believe that this finding will not only provide a new classification for the orbit of the Japanese population but also be clinically useful in orbital reconstruction.

ACKNOWLEDGMENTS

The authors are grateful to the staff of the Department of Plastic Surgery, Kobe University Graduate School of Medicine who gave of their time and expertise. The authors also thank Editage for English language editing.

REFERENCES

1. Sakakibara S, Hashikawa K, Terashi H, et al. Reconstruction of the orbital floor with sheets of autogenous iliac cancellous bone. *J Oral Maxillofac Surg* 2009;67:957–961
2. Gear AJ, Lokeh A, Aldridge JH, et al. Safety of titanium mesh for orbital reconstruction. *Ann Plast Surg* 2002;48:1–7
3. Gunarajah DR, Samman N. Biomaterials for repair of orbital floor blowout fractures: a systematic review. *J Oral Maxillofac Surg* 2013;55:550–570
4. Woo TL, Morant GM. A biometric study of the "flatness" of the facial skeleton in man. *Biometrika* 1934;26:196–250
5. Chalala C, Saadeh M, Ayoub F. Facial flatness indices: application in orthodontics. *PeerJ* 2019;7:e6889
6. Shimbo K, Ichinose A, Sakakibara S, et al. Measurement of the thickness of upper eyelid using microcoil magnetic resonance imaging. *J Jpn PRS* 2009;29:281–284
7. Oh TS, Jeong WS, Chang TJ, et al. Customized orbital wall reconstruction using three-dimensionally printed rapid prototype model in patients with orbital wall fracture. *J Craniofac Surg* 2016;27:2020–2024
8. Kim YC, Min KH, Choi JW, et al. Patient-specific puzzle implant preformed with 3D-printed rapid prototype model for combined orbital floor and medial wall fracture. *J Plast Reconstr Aesthet Surg* 2018;71:496–503
9. Vehmeijer M, van Eijnatten M, Liberton N, et al. A novel method of orbital floor reconstruction using virtual planning, 3-dimensional printing, and autologous bone. *J Oral Maxillofac Surg* 2016;74:1608–1612
10. Kozakiewicz M, Elgalal M, Loba P, et al. Clinical application of 3D pre-bent titanium implants for orbital floor fractures. *J Craniomaxillofac Surg* 2009;37:229–334
11. Mustafa SF, Evans PL, Bocca A, et al. Customized titanium reconstruction of post-traumatic orbital wall defects: a review of 22 cases. *Int J Oral Maxillofac Surg* 2011;40:1357–1362
12. Park SW, Choi JW, Koh KS, et al. Mirror-imaged rapid prototype skull model and pre-molded synthetic scaffold to achieve optimal orbital cavity reconstruction. *J Oral Maxillofac Surg* 2015;73:1540–1553
13. Nagasao T, Hikosaka M, Morotomi T, et al. Analysis of the orbital floor morphology. *J Craniomaxillofac Surg* 2007;35:112–119
14. Kang HS, Han JJ, Oh HK, et al. Anatomical studies of the orbital cavity using three-dimensional computed tomography. *J Craniofac Surg* 2016;27:1583–1588
15. Singh J, Rahman RA, Rajion ZA, et al. Orbital morphometry: a computed tomography analysis. *J Craniofac Surg* 2017;28:e64–e70
16. Hasan AH. Three dimensional computed tomography morphometric analysis of the orbit in Iraqi population. *Int Med J* 2017;24:147–149
17. Ji Y, Qian Z, Dong Y, et al. Quantitative morphometry of the orbit in Chinese adults based on a three-dimensional reconstruction method. *J Anat* 2010;217:501–506
18. Fitzhugh A, Naveed H, Davagnanam I, et al. Proposed three-dimensional model of the orbit and relevance to orbital fracture repair. *Surg Radiol Anat* 2016;38:557–561
19. Doerfler HM, Huempfner-Hierl H, Kruber D, et al. Template-based orbital wall fracture treatment using statistical shape analysis. *J Oral Maxillofac Surg* 2017;75:1475e1-1475.e8
20. Hanihara K. Dual structure model for the population history of the Japanese. *Jpn Rev* 1991;2:1–33
21. Baba H, Narasaki A, Ohyama S. Minatogawa hominid fossils and the evolution of late Pleistocene humans in East Asia. *Anthropol Sci* 1998;106:27–45
22. Oota N, Matsushita T, Ueda S. Molecular genetic analysis of remains of a 2,000-year-old human population in China—and its relevance for the origin of the modern Japanese population. *Am J Hum Genet* 1999; 64:250–258
23. Jinam T, Nishida N, Hirai M, et al. The history of human populations in the Japanese Archipelago inferred from genome-wide SNP data with a special reference to the Ainu and the Ryukyuan populations. *J Hum Genet* 2012;57:787–795
24. Mishima Y, Matsuo K, Yuzuriha S, et al. The supraorbital margin of Japanese who have no visible superior palpebral crease and persistently lift the eyebrow in primary gaze is higher and more obtuse than those who do not. *Eplasty* 2013;13:e39
25. Yamaguchi B. Facial flatness measurements of the Ainu and Japanese crania. *Bulletin of the National Science Museum* 1973;16:161–171
26. Yamaguchi B. A study on the facial flatness of the Jomon crania. *Bulletin of the National Science Museum V 6* 1980:21–28
27. Takigawa W, Sato T. Northeastern protohistoric people: physical traits of human skeletal remains from the Yamoto tunnel burials in Miyagi prefecture. *Anthropol Sci* 2008;116:35–51
28. Matsumura H, Hung HC, Higham C, et al. Craniometrics reveal "two layers" of prehistoric human dispersal in Eastern Eurasia. *Sci Rep* 2019;9:1451
29. Ichinose A, Tahara S. Extended preseptal fat resection in Asian blepharoplasty. *Ann Plast Surg* 2008;60:121–126
30. Chen WP. Concept of triangular, trapezoidal, and rectangular debulking of eyelid tissues: application in Asian blepharoplasty. *Plast Reconstr Surg* 1996;97:212–218
31. Flowers RS. Asian blepharoplasty. *Aesthet Surg J* 2002;22:558–568