The Relationship of the Globe to the Orbital Rim

Lauren A. Eckstein, MD, PhD; Joseph M. Shadpour, BS; Ravi Menghani, MD, MBA; Robert A. Goldberg, MD

Objective: To present a novel method for accurately characterizing the position of the globe relative to the orbital rim. The appearance and function of the eyelids are dependent on the underlying bony architecture and globe position; however, no comprehensive language to describe these complex 3-dimensional relationships exists.

Methods: Three-dimensional orbital reconstructions were generated from computed tomographic scans of 15 Occidental and 12 Oriental orbits without orbital pathologic disease. Globe and orbital rim anatomy were identified and outlined. Reference points were measured along 2 independent axes: (1) the distance between a plane defined by the corneal apex and the sagittal projection of the orbital rim and (2) the distance between the circumference of the globe and the coronal projection of the orbital rim.

Results: For Occidental orbits, the mean (SD) elevation of the sagittal projection of the orbital rim relative to the anterior projection of the globe was 4.6 (4.2) mm superiorly, 5.9 (3.0) mm nasally, 12.6 (3.7) mm inferiorly, and 20.6 (2.6) mm laterally. The mean (SD) radial distance between the coronal projection of the orbital rim and the circumference of the globe was 3.7 (2.1) mm superiorly, 7.6 (1.8) mm nasally, 6.6 (2.2) mm inferiorly, and 4.6 (2.3) mm laterally. For Oriental orbits, the mean (SD) elevation of the sagittal projection of the orbital rim relative to the anterior projection of the globe was 5.0 (4.5) mm superiorly, 6.8 (4.1) mm nasally, 11.1 (4.3) mm inferiorly, and 17.5 (3.3) mm laterally. The mean (SD) radial distance between the coronal projection of the orbital rim and the circumference of the globe was 2.1 (1.2) mm superiorly, 8.2 (2.0) mm nasally, 6.5 (1.9) mm inferiorly, and 4.5 (1.7) mm laterally.

Conclusions: Comparison of Occidental and Oriental orbital rim and globe configurations revealed quantitative and qualitative differences. In addition to differences in soft-tissue anatomy, bony architectural variations may contribute substantially to racial differences in the surface anatomy of the periorbital area. Anatomic analysis, based on 3-dimensional orbital imaging, may provide a rational approach to surgical planning for aesthetic and reconstructive orbitofacial surgery.


Author Affiliations: Scheie Eye Institute, University of Pennsylvania School of Medicine, Philadelphia (Dr Eckstein); and David Geffen School of Medicine (Dr Menghani) and Jules Stein Eye Institute (Dr Goldberg), University of California, Los Angeles (Mr Shadpour).
rangement of the globe and orbital rim. We further inves-
tigated variations in these relationships between Occiden-
tal and Oriental patients. Anatomic analysis of orbital bony
contours relative to the globe, based on 3D orbital imaging,
may provide a rational approach to surgical planning for
aesthetic and reconstructive orbitofacial surgery.

**METHODS**

A retrospective review of the electronic patient registry
(McCann Medical Matrix, St Louis, Missouri) of the Orbital and
Ophthalmic Plastic Surgery Division of the Jules Stein Eye In-
stitute at the University of California, Los Angeles, was con-
ducted. Patient records that included high-resolution spiral com-
puted tomographic (CT) scans (1-mm slice width or less) of the
orbits were identified. Medical records were then reviewed to ex-
clude patients with bilateral orbital trauma, tumors, thyroid-
related orbitopathy, or other orbital pathology. Finally, self-
reported demographics were used to identify Occidental and
Oriental data sets. Twelve Occidental (mean age, 46 years) and
7 Oriental patients (mean age, 32 years) were identified, yield-
ing 15 Occidental and 12 Oriental orbits without orbital patho-
logic conditions. The study was approved by the University of
California, Los Angeles, institutional review board.

Digital Imaging and Communications in Medicine (DICOM)
files were imported into ImageJ (National Institutes of Health,
Bethesda, Maryland), a public domain image processing program,
and volume-rendering 3D orbital reconstructions were generated
with the Volume Viewer plug-in (Internationale Medieninforma-
tik, Berlin, Germany). Reconstructions were generated in both
the coronal and the sagittal planes, and transections through the skull
with attention to the skull base were rendered to align the clinoid
processes as well as the sella nasion, thereby orienting the skull
in 3 dimensions for further analysis.

Next, transections displaying both soft and bony tissues
through the orbits at the depth of the equator (circumference)
of the globes were generated (Figure 1A). The rendering depth
was then adjusted to display the orbits from a perspective an-
terior to the orbital rim, and the rendering threshold was ad-
justed to exclusively display bony tissue (Figure 1B). These 2
sets of images were then imported into Adobe Illustrator (Adobe
Systems Incorporated, San Jose, California) and overlaid into
a single composite reconstruction of the globe and coronal pro-
jection of the orbital rim (Figure 1C).

The orbital reconstructions were subsequently rotated 90°
along the horizontal plane to yield sagittal projections. Once
again, transections displaying both bony and soft tissues
through the center of the cornea were generated (Figure 1D).
The rendering depth was then adjusted to display the orbits from a perspective lateral to the orbital rim, and the rendering
threshold was adjusted to display exclusively bony tissue
(Figure 1E). As before, these 2 sets of images were imported
into Adobe Illustrator and overlaid into a single composite recon-
struction of the globe and coronal projection of the orbital rim (Figure 1F).

For clarity, globe and orbital rim anatomy were outlined with
Adobe Illustrator (Figure 2A and B), and 360° polar plots
were overlaid. The anatomic configuration of the axial cross-
section of the globe was approximated as a circle. For both the
right and left orbits the medial orbital rim was assigned 0°, the

**Figure 1.** Reconstruction of orbital rim and globe. A, Coronal transection through equator of the globe. B, Coronal reconstruction of the orbital rim. C, Coronal
transection and reconstruction superimposition. D, Sagittal transection through the apex of the cornea. E, Sagittal reconstruction of the orbital rim. F, Sagittal
transection and reconstruction superimposition.

**Figure 2.** Orientation and landmark identification of orbital rim and globe. Outline of the orbital rim and globe in coronal plane (A) and sagittal plane (B). Overlay of polar plot in coronal plane (C), identification of corneal apex and cardinal points in sagittal plane (D), and alignment of coronal and sagittal reconstructions (E).
inferior orbital rim was assigned 90°, the lateral orbit was assigned 180°, and the superior orbit was assigned 270° (Figures 2C and D). Thus, the orientation of the right and left orbits are a mirror image of one another, and the localization of points along the orbital rims may be readily compared between right and left orbits. The coronal and sagittal reconstructions were then aligned, and the precise localization of points at 30° intervals were projected from the coronal reconstruction to the sagittal reconstruction (Figure 2E).

The distances between the equator of the globe and the coronal projection of the orbital rim and between the corneal apex plane and the sagittal projection of the orbital rim were measured at 30° intervals with the measuring tool in Adobe Illustrator. The bony anatomy adjacent to the medial canthal tendon (0°), characterized by the broad confluence of the posterior and anterior lacrimal crest, precludes confident ascertainment of the orbital rim at this location. Therefore, this point was estimated, and as a result, detailed orbital rim analysis was carried out from 30° to 330°. Importantly, previous work has validated the utility of CT-based 3D volume rendering for the purpose of anthropological craniofacial studies of both bone and soft-tissue measurements. A set of 360° plots (Goldberg-Eckstein curves) were developed to graphically display these data sets (Figure 3). Measurements are reported as the mean (SD), and the 1-sided t test was used to identify significant (P≤.05) measurements.

Data from 15 Occidental orbits (representing 12 unique patients) and 12 Oriental orbits (representing 7 unique patients) were analyzed, and Goldberg-Eckstein curves were generated. For Occidental orbits the mean (SD) radial distance between the coronal projection of the orbital rim and the circumference of the globe was 3.7 (2.1) mm superiorly, 7.6 (1.8) mm nasally, 6.6 (2.2) mm inferiorly, and 4.6 (2.3) mm laterally. For Oriental orbits the mean (SD) radial distance between the coronal projection of the orbital rim and the circumference of the globe was 2.1 (1.2) mm superiorly, 8.2 (2.0) mm nasally, 6.5 (1.9) mm inferiorly, and 4.5 (1.7) mm laterally (Figure 4A).

Comparison of these measurements demonstrated a statistically significant greater distance between the edge of the globe and the superior orbital rim in Occidental patients compared with Oriental patients. Inferiorly, there was no significant difference in the relative positioning of the globe and orbital rim. These data revealed that the
Occidental orbit was taller than the Oriental orbit. That is, although the positioning of the globe in the coronal plane relative to the inferior orbital rim was equivalent in Occidental and Oriental patients, the orbital aperture extended further superiorly in Occidental orbits. Thus, the Occidental orbital rim demonstrated a superior “vault.”

Although when plotted as a Goldberg-Eckstein curve, the space between the globe and the orbital aperture in the coronal plane was found to have a greater area in Occidental patients (115.4 mm²) compared with Oriental patients (106.2 mm²), the observed superior vault of the Occidental orbital rim demonstrated a superior “vault.” In this region, the mean slope of the orbital rim in the Occidental population was 0.12 mm/degree, whereas the average slope of the orbital rim in the Oriental population was 0.10 mm/degree (Figure 5B)—a statistically significant difference (P = .01). Thus, in addition to the previously described superior vault, the average Occidental orbital rim is flared posteriorly when observed from the sagittal plane compared with the average Oriental orbital rim.

Traditional analysis of the periocular region has focused on the surface anatomy of this area. Because of the ease of observation and the facility of surgical manipulation, investigations have concentrated on numerous associated structures, including the architecture of the eyelids and the shape and position of the forehead and midface. However, the anatomy of this region is profoundly influenced by the deep tissue architecture—the 3D curvature of the orbital rim, the localization of the globe, and the complex interplay between the two. Although qualitative descriptions of this relationship abound, quantitative analysis of this anatomy is limited.

Historically, practitioners have relied on Hertel exophthalmometry to characterize this relationship. However, this instrument, and other similar devices, only permit measurement of the position of the globe relative to the lateral orbital rim. Moreover, it is affected by parallax errors as well as by bony or soft-tissue asymmetries between the right and left sides of the skull and face, which may be caused by disease processes, following trauma, or iatrogenically induced. In addition, measurements are significantly affected by both interobserver and intraobserver variation even with newer instruments.

Even if a perfect exophthalmometer could be developed, the measurement is limited to a single point of reference. More valuable for understanding and describing the relationship of the globe and its bony support is a 3D description across the entire 360° sweep of the orbital rim. We have presented a technique for describing the position of the globe relative to any point on the orbital rim. By exploiting advances in computing power and the availability of 3D reconstructions, this CT-based approach enables measurement in any anatomic axis. Previous studies have validated the accuracy of CT-derived exophthalmometry measurements.

One application of this imaging-based approach is better assessment of proptosis or enophthalmos in the set-

---

Figure 5. Comparative analysis of Occidental and Oriental rims in the sagittal plane. A, Comparison of the mean elevation of Occidental and Oriental rims in the sagittal plane. B, Scatter plot detailing the slope of the inferior orbital rim between 30° and 150° in the sagittal plane. Open circles represent individual data points; solid bars indicate mean value across all samples in the group.

(Reprinted) Arch Facial Plast Surg/Vol 13 (No. 1), Jan/Feb 2011 www.archfacial.com

©2011 American Medical Association. All rights reserved.
Depression of the lateral orbital rim as is seen in orbitozygomatic fractures can also induce errors into Hertel measurements. If the absolute position of the globe (relative to stable points on the skull, such as the superior orbital rim) is essentially unchanged, the globe will falsely appear to be proptotic based on simple Hertel exophthalmometry (pseudoproptosis). Because a 3D imaging–based analysis enables quantification of the position of the globe relative to multiple structures (such as the superior orbital rim), it can better characterize the globe position relative to these confounding bony changes.

Our comparison of Occidental and Oriental orbital rim anatomy has revealed numerous qualitative and quantitative differences in the shape of the orbital rim and the position of the globe within the orbital aperture between these 2 groups. For instance, the Occidental orbit rim vaults superiorly (in the coronal plane). This specific bony characteristic may affect the soft-tissue draping and contribute to observed racial differences in surface anatomy. Likewise, our finding that the Oriental orbital rim is flatter and shallower (in the sagittal plane) than the Occidental oriental rim may help to explain the differences in the surface anatomy of this region.

Interestingly, on average, in both the Occidental and Oriental populations, the “deepest” extent of the orbit (as viewed from the sagittal plane) was inferior-lateral at 150°. Because of its inherent geometric limitations, Hertel exophthalmometry has permitted measurement only at 180° (presuming that the instrument is placed correctly), and thus has focused our attention at this point. However, a more informative position may instead be slightly inferior; the implication of this finding and its significance to periocular soft-tissue anatomy remains to be elucidated in future studies.

Numerous studies have focused on aging changes in the bony elements of the face. In particular, a progressive decrease in the glabellar angle and a suborbital retrusion of the maxillary face has been observed in both male and female skulls with advancing age. The authors of these studies speculate that these changes may contribute to brow ptosis, lateral orbital hooding, midface descent, and increased prominence of the nasolabial folds.

Interestingly, examinations of age-related changes in the bony anatomy of the orbital rim and periocular soft tissue reveal inconsistent results. Studies by Mendelson et al have demonstrated stable orbital floor length with advancing age, whereas investigations by Pessa et al have revealed a posterior retrusion of the inferior orbital rim relative to the anterior cornea. However, these latter results may be due to changes in retrobulbar orbital soft tissues (eg, orbital fat expansion) or sinus air cell expansion, which may result in an apparent anterior displacement of the globe relative to a stable orbital rim.

Changes in the structure of the orbital rim would be expected to have a direct and profound impact on the overlying soft-tissue anatomy. A cross-sectional analysis of age-related changes in the orbital aperture revealed an increase in the superomedial height and inferolateral depth of the coronal projection of the orbital rim. Importantly, however, no significant change in the overall height or width of the orbital aperture was observed. The authors speculate that the curve distortion of the orbital rim may contribute to the appearance of canthal malposition, the curve of the upper eyelid margin and supraciliary eyelid crease, the shape of the eyebrow, and other aspects of eyelid surface anatomy and aesthetics. Other studies have demonstrated a significant relationship between the angle of the maxillary sinus face (shown to decrease with advancing age) and the presence of a tear trough deformity, as well as the position of the globe relative to the orbital rim and the presence of lower eyelid retraction.

For instance, variations in the deep, bony anatomy contribute to soft-tissue findings such as upper eyelid crease position and contour. Obvious examples are disorders that significantly change the relationship between bone and soft tissues, such as facial fractures, which alter the periorbital bony anatomy, and orbital diseases, which produce enophthalmos or proptosis.

More subtle, but important, are the inherited variations and aging changes in the bony structures that underlie the heterogeneity of periorbital appearance. Bony asymmetry results in visible surface asymmetries of eyelid contour, such as crowded appearing orbits, eyebrow asymmetry, sulcus and upper eyelid crease asymmetry, and canthal asymmetry. Moreover, the 3D shape of the inferior orbital rim bony support directly affects the visible contours and position of the lower eyelid soft tissues and similarly contributes to lower eyelid asymmetry. Improved understanding of the contribution of the underlying bony anatomy to soft-tissue contour and symmetry may contribute substantially to planning for surgical management of these important aesthetic concerns. Therefore, 3D anatomic analysis may provide a rational approach to surgical planning for aesthetic and reconstructive orbitofacial surgery.

Oculofacial surgeons understand intuitively that deep-tissue anatomy contributes substantially to the structure and function of the periorbital soft tissues. Moreover, the contour of the orbital rim and the relative position of the globe subserve the aesthetics of the orbital facial subunit. The novel 3D anatomic analysis of these complex relationships presented herein provides a basis for a unique, comprehensive language with which to quantitatively describe periorbital bony architecture and dependant soft-tissue anatomy as well as its natural and pathologic variations.

Accepted for Publication: May 28, 2010.

Correspondence: Robert A. Goldberg, MD, Jules Stein Eye Institute, University of California, Los Angeles, 100 Stein Plaza, Los Angeles, CA 90095 (goldberg@sei.ucla.edu).

Author Contributions: Study and design: Eckstein, Shadpour, Menghani, and Goldberg. Acquisition of data: Eckstein, Shadpour, and Menghani. Analysis and in-

Financial Disclosure: None reported.

Previous Presentation: This study was presented at the American Society of Ophthalmic Plastic and Reconstructive Surgery Annual Fall Scientific Symposium; November 9, 2007; New Orleans, Louisiana.

REFERENCES


Visit www.archfacial.com. As an individual subscriber you can search the full text of Archives of Facial Plastic Surgery or all 10 JAMA and the Archives Journals. Advanced Search enables you to search by citation, title, author, keywords, and date ranges. You can search by journal or by topic collection. Finally, you can choose to search only tables and figures.

©2011 American Medical Association. All rights reserved.