J Forensic Sci, March 2009, Vol. 54, No. 2
doi: 10.1111/j.1556-4029.2008.00982.x
Available online at: www.blackwell-synergy.com

TECHNICAL NOTE

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Further Evidence on the Anatomical Placement of the Human Eyeball for Facial Approximation and Craniofacial Superimposition*

ABSTRACT: Recently a small sampled cadaver study (n = 4) suggested that the human eyeballs are placed closer to the orbital roof and lateral orbital wall as first reported in the anatomical literature many years previously. This contrasts with central positioning of the eyeball within the orbit as advocated by the facial approximation literature. Given the limits of such small samples, this study re-examined globe position in nine new cadavers to help clarify which relationship is accurate. The results essentially confirm prior empirical findings except that the mean lateral divergences from the orbit center were found to be larger—the eyeball was found to be "displaced" 1.4 mm superiorly and 2.4 mm laterally. Medians calculated across all 13 cadavers from this study and the above-mentioned recent report refine these measurements to 1.4 and 2.3 mm respectively. Globe projection values were identical to those observed for living individuals (*c*. 16 mm).

KEYWORDS: forensic science, facial reconstruction, facial reproduction, craniofacial superimposition, globe

Determination of the eyeball position is one of the first considerations undertaken in craniofacial superimposition (1) and facial approximation (2,3). Because methods ultimately depend on accurate anatomical understandings of the soft tissue relationships to the skull, accurate knowledge of the position of the eyeball and the surrounding soft tissue features is important. This is especially the case for facial approximation where the constructed faces are advertised to generate facial recognitions—a process widely known to depend on the morphology of the orbital region (4–7).

Recently, empirical evidence has been put forth to suggest that the globe, rather than being centrally positioned within the orbit, should be positioned 1.5 mm closer to the superior and lateral orbital margins (8). Despite corroboration of these results by much earlier anatomical studies (see 9,10) generalizations remain problematic because these other studies have aged and the sample size of the more recent report is small (n = 4). Confidence in the central positioning rule is also not encouraged because it appears to be based on speculative grounds rather than empirical evidence. This study re-examines the eyeball and canthi position in nine new cadavers to help clarify which prediction guideline is accurate. While this new sample remains relatively small, it is sizable for studies of cadaveric material where specimen availability is often limited.

Materials and Methods

Nine new cadavers were dissected in this investigation, including six males and three females with a mean age of 81 years (s = 8 years). These cadavers were embalmed by the administration of 18–20 L of preservation fluid (for an average-sized body) via the femoral artery. The embalming fluid comprised a 20:1 mix of Dodge® Anatomical Arterial Mixture® (Dodge, Cambridge, MA) and Dodge® Plasdopake Tissue Texturizer® (Dodge). Prior to dissection, all cadavers had been strictly stored in the supine position and without pressure to the face. While the cadavers doubled as teaching specimens during the pre-dissection period (the limbs and torso were subjected to a basic and accelerated dissection class over a <6-week period), the cadavers were rarely turned to the prone position and were always stored supine. At the time of dissection, the heads were sectioned from the body after a mean time of 424 days since the administration of embalming fluid.

Dissection procedures essentially identical to those reported by Stephan and Davidson (8) were used, with the exception that canthi positions were not a concern in this study. After the soft tissue lying adjacent and anterior to the geometric equator of the globe had been removed, the eyeball position was measured with respect to three axes: superoinferior, anteroposterior, and mediolateral. In the coronal plane, two different methods were used. First, the distance between the center of the pupil and each orbital margin was measured. Second, the distance between each of the four globe edges and their respective orbital walls was measured. These two methods enabled globe position to be double checked in case the pupils had not been facing directly ahead—this was difficult to judge by opening the eyelids and was not evident until the dissection was well underway. Because the globe is largely "suspended" in fat, special care was taken to remove only the smallest amount necessary to enable measurement.

Divergences from the center of the orbit were calculated by subtracting the lateral from medial measurements, and the superior from inferior measurements, and dividing by two in each instance. Anterior eyeball projection was measured from the deepest portion of the lateral orbital wall to the corneal apex

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*Portions of this work have been presented at the 60th Annual Meeting of the American Academy of Forensic Sciences, February 2008, Washington DC, U.S.A.

Received 17 Mar. 2008; and in revised form 23 May 2008; accepted 1 June 2008.

using a Hertel-type Western Ophthalmics exophthalmometer (Western Ophthalmics, Lynnwood, WA).

Results

The eyeball positions were generally found to be closer to the orbital roof and lateral orbital wall following trends reported by Stephan and Davidson (8), Whitnall (9), Wolf (11), and Goldnamer (10). Mean distances from the globe edge and pupil center are presented in Fig. 1 while all nine dissections (left side) are presented in Fig. 2. Summary statistics are presented in Table 1. Mean globe projections from the lateral orbital wall were typical of values reported by other investigators using living samples (12–18; see Fig. 3). Pooling the raw data from this study and that by Stephan and Davidson (8) yielded median divergences from the orbital center of 1.4 mm superiorly and 2.3 mm laterally. Median globe projection values from the combined data was 16.8 mm (n = 11).

Discussion

This study demonstrates that the more superior and lateral positioning of the globe is a repeatable finding across human cadavers. In regards to the pooled sample derived from this study and that by Stephan and Davidson (8), 85% of cadavers displayed this pattern. Only two of the 13 cadavers (15%) showed anatomies which approximated the central positioning guideline as previously used in craniofacial identification. The consistently more superior and lateral placement of the eyeball, together with similar observation by Whitnall (9), Wolf (11), and Goldnamer (10), provides strong support that this relationship can be generalized to at least Caucasoid samples and probably to larger populations. These findings clearly indicate that the central positioning eyeball rule should be abandoned in craniofacial identification practice in favor of more superior and lateral placement.

The finding that globe projection values of cadavers were comparable with those for living people (see Fig. 3), supports claims

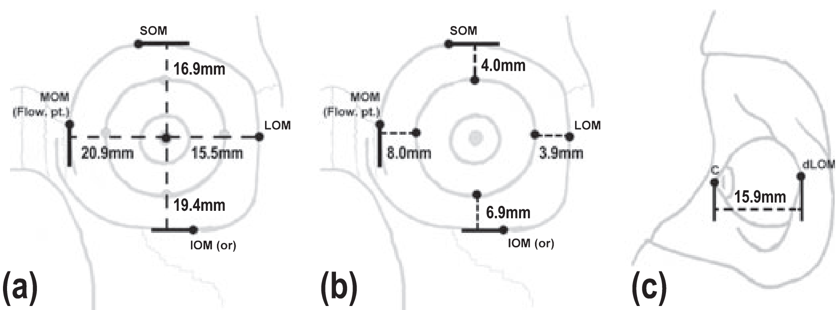

FIG. 1—*Mean eyeball positions in nine cadavers. (a) Measurements to the pupil center (n = 9). (b) Measurements to the globe edge (n = 9). (c) Globe projection measurement (n = 7). Landmarks: MOM, medial orbital margin identified by Flower's point (Flow. pt.); LOM, lateral orbital margin identified by its lateral most aspect; SOM, superior orbital margin identified by its superior most aspect; IOM, inferior orbital margin identified by orbitale; c, corneal apex; dLOM, deepest point on lateral orbital margin.*

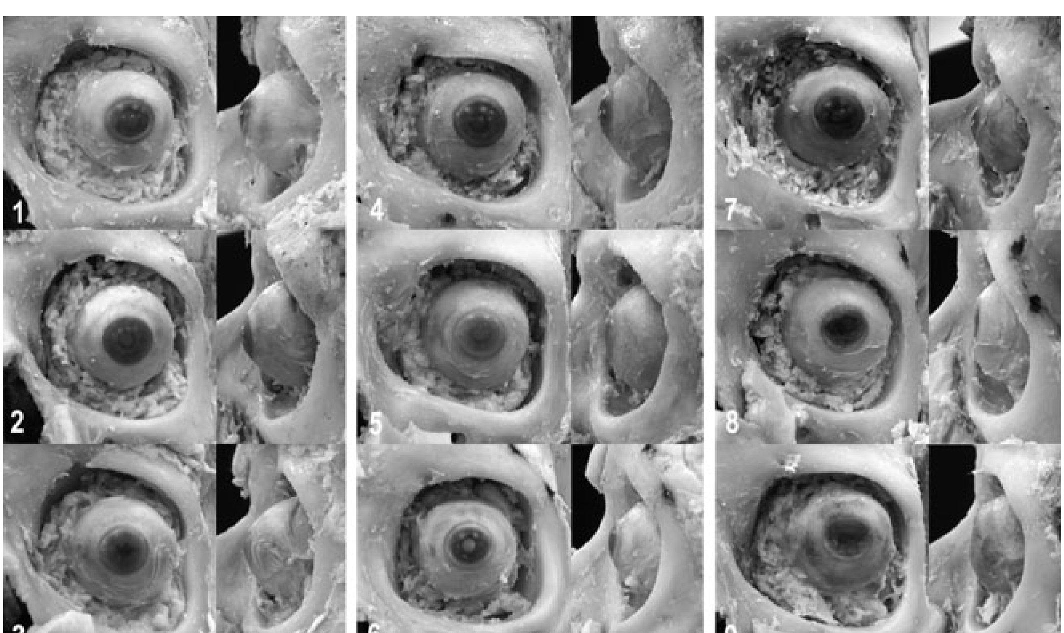

FIG. 2—*Individual eyeball positions in nine cadavers (left side). Note that globe projection values were not taken from the last two specimens exhibiting dimpled anterior cavities (see No. 8 and 9).*

TABLE 1—*Summary data for the variables measured in this study.*

	Mean	*s*	Minimum	Maximum	*n*
Age of subjects (years)	81.3	7.9	67.0	93.0	9
Time embalmed (days)	424.2	158.2	272.0	690.0	9
SOM-Pupil center (mm)	16.9	2.0	14.7	20.5	9
IOM-Pupil center (mm)	19.4	1.3	17.7	21.5	9
LOM-Pupil center (mm)	15.5	0.8	14.3	16.7	9
MOM-Pupil center (mm)	20.9	1.7	18.3	22.8	9
SOM-Superior edge of globe (mm)	4.0	1.3	2.0	5.8	9
IOM-Inferior edge of globe (mm)	6.9	1.1	4.8	8.3	9
LOM-Lateral edge of globe (mm)	3.9	0.6	2.7	4.5	9
MOM-Medial edge of globe (mm)	8.0	1.5	5.3	9.5	9
Globe projection from dLOM (mm)	15.9	2.6	12.8	20.2	7

MOM, medial orbital margin; LOM, lateral orbital margin; SOM, superior orbital margin; IOM, inferior orbital margin; dLOM, deepest point on lateral orbital margin.

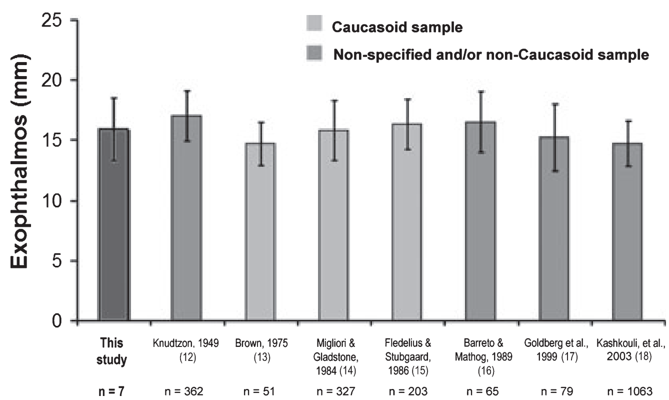

FIG. 3—*Eyeball projection from the lateral orbital rim as measured in cadavers by the current authors, and in living individuals by other authors. The bars represent one standard deviation on either side of the mean.*

that recent craniofacial identification methods underestimate globe projection (7) and indicates that the use of cadavers in this study did not compromise the validity of the results. The high similarity of eyeball projection results between cadavers and living persons indicates that tissue swelling was not an issue for concern in this study. This is not surprising because initial soft tissue swelling after embalming fluid administration is known to subside after a curing period of about 6 months (see e.g., 19) and the cadavers used here had been embalmed for an average period of more than 1 year. Movement of the eyeball during the cadaver storage phase is also not expected to have been a major influencer on the results because the embalming process acts to harden the tissues and fix them in place. While a small chance for compression to the orbital region existed because some of the specimens may have been rolled into the prone position (and then back into supine) during teaching classes conducted in the pre-dissection period, the direction of compressive forces arising from the turning of the head into the prone position (and against the dissecting gurney) would likely push the eyeball in a direction opposite to those displacements observed in this study (i.e., medially and posteriorly). This would act to counter the results of this study rather than exacerbate them. Thus, the results reported here continue to hold empirical validity and practical application to facial approximation and superimposition methods. However, as this study was based on an elderly cadaver sample, future research investigating younger living individuals would be advantageous.

Acknowledgments

The author's special thanks go to staff at the University of Queensland's Anatomy Laboratory for technical assistance and to two anonymous reviewers who provided helpful comments.

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