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Current Methods for Brow Fixation: Are They Safe?

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Abstract. *Background:* No single technique for fixation of the scalp after forehead-lift is universally accepted. Complications such as alopecia, loss of elevation, implant palpability, paresthesia, and dural injury are possible with the variety of techniques used currently. This anatomic study was designed to evaluate the thickness of the calvarium at selected points used in brow fixation. The depth of cranial penetration necessary for currently used techniques is measured and compared.

Methods: In a study of 14 fresh adult cadavers, calvarial thickness was measured at selected points (A–F) used in various brow-lifting procedures. This was accomplished by drilling holes in selected points and using a depth gauge to measure thickness. Immediately adjacent to selected points, the cranium is prepared for brow fixation using the following techniques: cortical tunnels, 2.0-mm screw fixation (10, 12, and 14 mm), the Mitek 2.0-mm Quickanchor screw, and the Endotine 3.5 Forehead Device. The depths required for adequate fixation and the potential for cranial penetration through the inner table with all the standard techniques are compared.

Results: Depth analysis by mean values showed that sites posterior to the coronal suture (points C–F) were thickest. Depth analysis of sites stratified by gender showed that mean values for the thickness of female skulls were greater than those for males. A review of fixation methods found that cortical tunnels at 45° angles never penetrated the inner table in any of the 14 skulls. Mitek screws never penetrated the inner table, and one Endotine post penetrated the inner table on the left side of one cadaver skull. After placement of 10-, 12-, and 14-mm miniscrews at each of the sites, it was found that three penetrated the inner table. The penetrations all were at far lateral sites, posterior to the coronal suture.

Conclusion: Variation in skull thickness exists among cadaver specimens at different sites on the skull. In this study, thickness increased medially and posteriorly. Women tended to have thicker skulls than men, and age was not a major variable. This is consistent with findings in previous work. Given the unpublished reports of inner table penetration, with cerebrospinal fluid leak after invasive brow fixation, it behooves the surgeon to keep in mind the anatomy of the calvarium and its nuances.

Key words: Brow fixation—Brow-lift—Cortical tunnels—Cranial thickness—Forehead lift—Skull thickness

No single technique for brow fixation is universally accepted, although many have been described in the plastic surgery literature. The evolution of brow-lifting from the traditional coronal approach with direct skin excision to more limited approaches, including those involving endoscopic visualization, has led to numerous methods of fixation. Rohrich and Beran [16] classified fixation techniques as either endogenous or exogenous. Examples of endogenous methods include galea-frontalis advancement, suspension sutures, bolster sutures, cortical tunnels, and tissue adhesives. Exogenous methods may involve the use of external or internal screws, miniplate fixation, Mitek screws (Ethicon, Norwood, MA, USA), K-wires, and, more recently, the Endotine Forehead Device (Coapt Systems, Inc., Palo Alto, CA, USA) and resorbable screws.

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Each brow fixation technique has been described with its own set of advantages and disadvantages. An undercurrent of controversy exists over the ultimate longevity of elevation, as compared with the coronal brow-lift, largely considered to be the gold standard to which other methods are compared [11]. Each method of brow fixation carries its own risks, and possible complications of currently used techniques include partial (and less commonly total) alopecia, loss of elevation, implant palpability, scalp pruritis, paresthesia, and the potential for dural injury. The significance of dural injury, with the risk of cerebrospinal fluid leak, and anecdotal case reports of this complication (which we believe is likely underreported) prompted this study.

The calvarium is formed by outer and inner tables of compact bone with a small amount of cancellous bone in the marrow space (diploë). The calvarium is formed purely by intramembranous ossification, as compared with the long bones of the body, which are formed by endochondral ossification [10]. Knize [8] described four large diploic veins without accompanying arteries, which can pass transversely through the skull and could be potentially penetrated by a fixation screw, although the risk of intracranial bleeding is low. He described how the frontal (anterior) branch of the middle meningeal artery can create deep depressions along the inner table of the skull, with large venous lakes, or lacuna lateralis, possibly eroding the inner table to produce thin areas of bone. In his series, the thickness of the skull at such an erosion was measured to be 3.404 mm. At these thin areas, a fixation screw could unintentionally penetrate the inner table of the skull.

Given the anatomic variations in the human calvarium, which previously have been described [1,7–9,13,14,17,18,20], our study aimed to evaluate the thickness of the calvarium at selected points traditionally used in brow fixation. Also, the depths of cranial penetration necessary for currently used techniques were measured and compared.

Materials and Methods

The skulls of 14 fresh adult cadavers (7 men and 7 women, 13 whites and 1 black) were evaluated. The ages of the cadavers ranged from 51 to 97 years.

The calvarial thickness was measured at selected points used in various brow-lifting procedures, and these points were labeled A to F. Points A and B were on the left and right, respectively, 1 cm posterior to the anterior hairline and perpendicular to the brow arch. Point C was on the far left side, 3 cm posterior to the anterior hairline and 7.5 cm from the midline (aligned with the lateral orbital rim). Point D was on the medial left side, 3 cm from the midline aligned with the medial canthus. Point E was at the medial right 3 cm from the midline, and point F was at the far right 7.5 cm from the midline. These points are displayed in preoperative marking and after calvarial exposure in Fig. 1a and b.

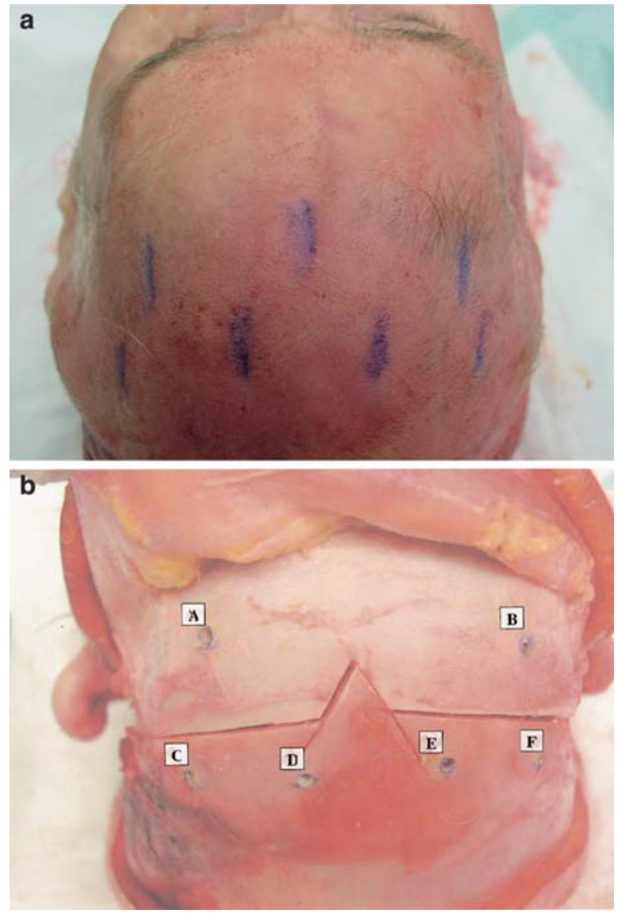


Fig. 1. Selected points for measuring calvarial thickness, labeled A–F. These points are displayed in preoperative marking **(a)** and after calvarial exposure **(b)** .

Proposed incisions were marked and made, and an electric drill was used to penetrate the calvarium at the selected points. Coronal exposure of the skull was undertaken, and a depth gauge was used to measure cranial bone thickness (Fig. 2a and b). Osteotomies then were made along the coronal suture, and the calvarium was evaluated from its inner surface (Fig. 3a and b). After these measurements had been made, the cranium was prepared for brow fixation immediately adjacent to the selected points. These new sites were labeled A' to F', accordingly. The following were used: cortical tunnels, 2.0-mm screw fixation (Synthes Maxillofacial, Paoli, PA, USA), Mitek Tacit Quickanchor (DePuy Mitek, Norwood, MA, USA), and the Endotine 3.5 Forehead Device. After this had been done, the depth required for adequate fixation, the potential for inner table penetration, and scalp thickness in relation to age, gender, and race were assessed.

The senior author's preferred technique was used for making cortical tunnels [20]. This procedure

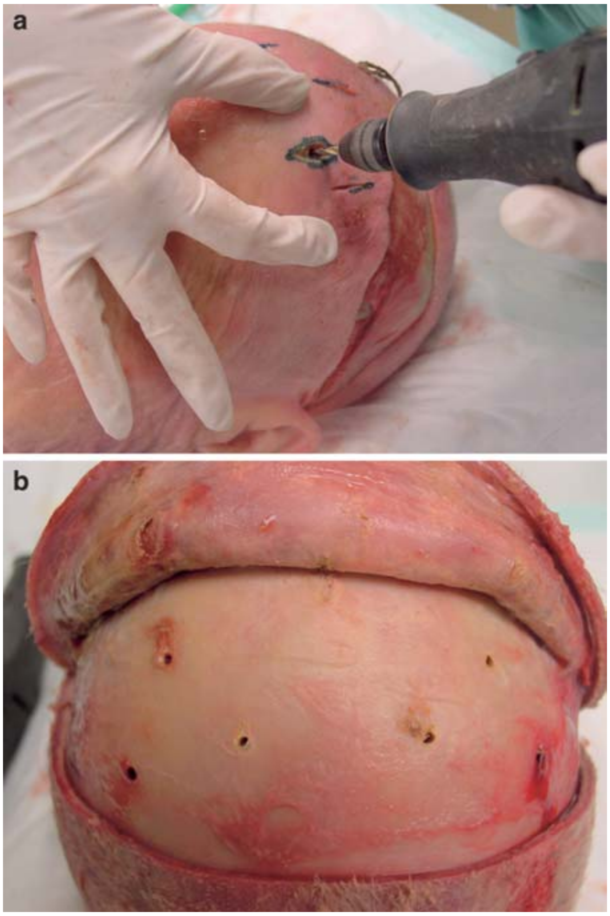


Fig. 2. Penetration of the skull by the electric drill at selected sites **(a)** and coronal exposure of the skull **(b)**.

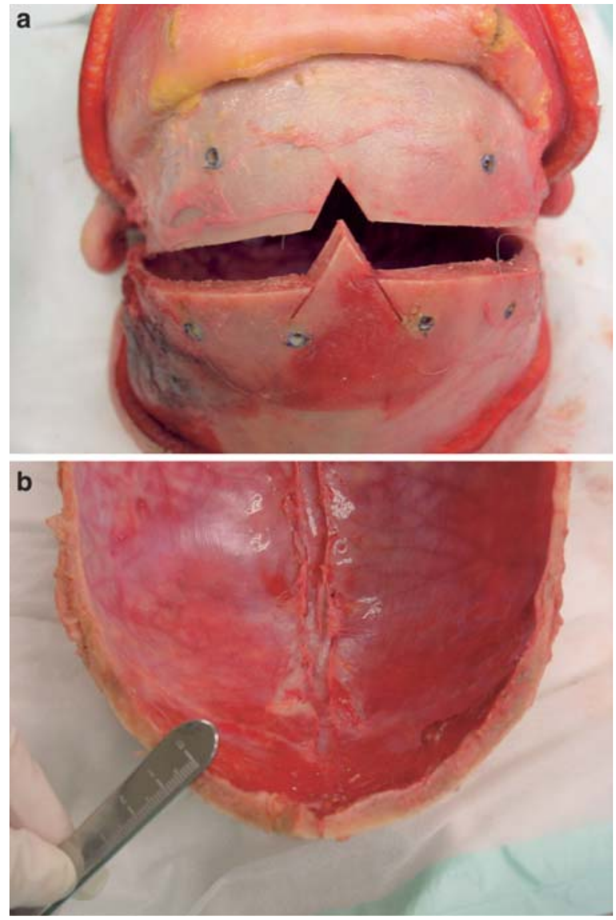


Fig. 3. Osteotomies made along coronal suture **(a)** and inner surface of the evaluation skull **(b)**.

requires the use of the Surgairtome Two gas-powered drill (Hall Surgical, Largo, FL, USA) with a 4.0-mm guarded drill bit (Fig. 4). Cortical tunnels are made at 45° angles beveling toward each other so that they meet. The tunnels were made adjacent to the four posterior sites C to F, all posterior to the coronal suture (Fig. 5). At the four posterior sites C' to F', 10-, 12-, and 14-mm self-tapping titanium miniscrews were placed at an angle perpendicular to the cranium (Fig. 6a and b). Screws of varying sizes were placed according to the technical descriptions of several different authors [15,20].

The Mitek Quickanchor is a 4.0-mm titanium screw used to anchor suture within predrilled bone sites for securing soft tissue to bone. It is attached to a 2.0 white Ethibond suture and double-armed with a tapered needle attached to a 1.7×4.0-mm screw. The system comes with a disposable inserter and drill bit. With the Mitek screw, proper hole depth is achieved when the shoulder stop touches the bone, which leaves a visible countersink. The Mitek Quickanchor is screwed in and disengages from the inserter, with the suture deployed by lifting of the inserter from the site (Fig. 7a and b). In this study, the screw was placed at the two anterior sites (A' and B'). This is

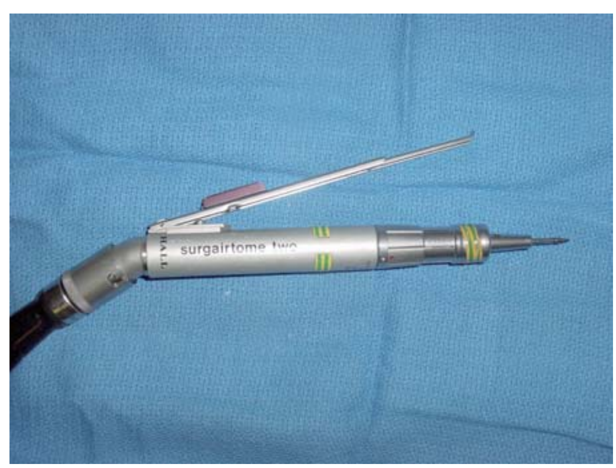


Fig. 4. Example of the gas-powered drill with a guarded 4-mm drill bit used to make cortical tunnels.

similar to Owsley's description of placing it 1 cm behind the anterior hairline for brow fixation [6].

The Endotine 3.5 Forehead Device comes with a 4-mm guarded drill bit for creating a hole, and the user is instructed to drill all the way to the drill bit

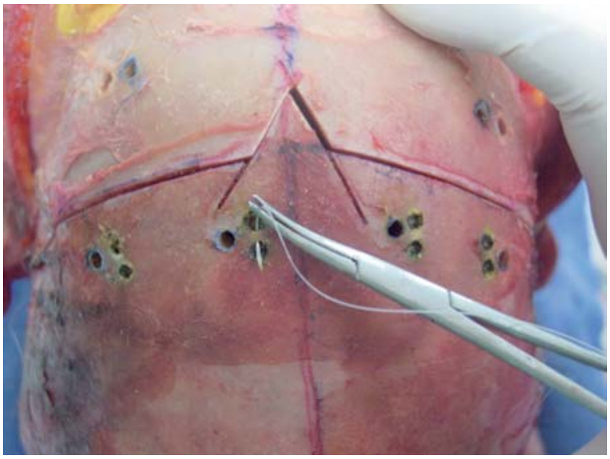


Fig. 5. Technique used to fashion cortical tunnels at 45–45° angles, with suture needle shown passing through aperture.

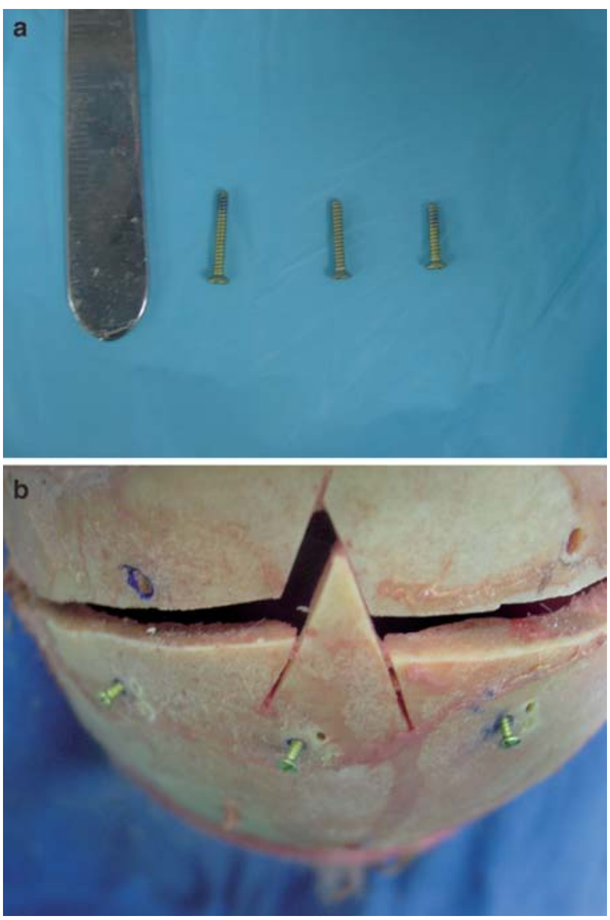


Fig. 6. Titanium miniscrews (10, 12, and 14 mm) used **(a)** and placed at an angle perpendicular to the cranial outer table **(b)**.

shoulder. An insertion tool is used to grasp the bio-absorbable implant, which is composed of a lactic acid/glycolic acid polymer [19] (Fig. 8a and b). The

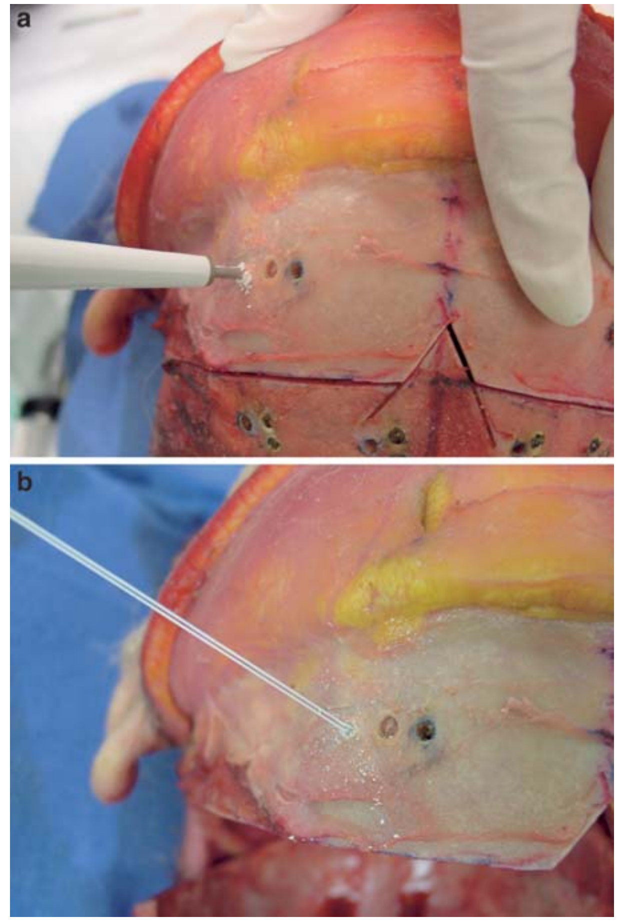


Fig. 7. Example of the Mitek screw being placed within bone **(a)** and suture being deployed by lifting of the inserter from the skull site **(b)**.

Endotine has a 3.75-mm implant post, which is seated into the hole and pushed until the platform is seated flush with the cranium. It is placed medial to the temporal fusion line and anterior to the coronal suture, as the manufacturer recommends [12], which corresponds with sites A' and B'. The scalp then is elevated, and digital pressure is applied to ensure penetration of the implant tines (Fig. 9a and b).

Results

The results of depth analysis by site are shown in Figure 12a, with the mean value for each of the sites A to F on the 14 cadaver heads seen in Fig. 10. This also is depicted graphically in Figure 12, which shows that the sites posterior to the coronal suture (C–F) were the thickest.

Depth analysis of the sites stratified by gender is seen in Figure 13. The mean values for the thickness of the female skulls were greater than those for male skulls at all sites A to F. In a review of fixation methods, we found that cortical tunnels at 45° angles

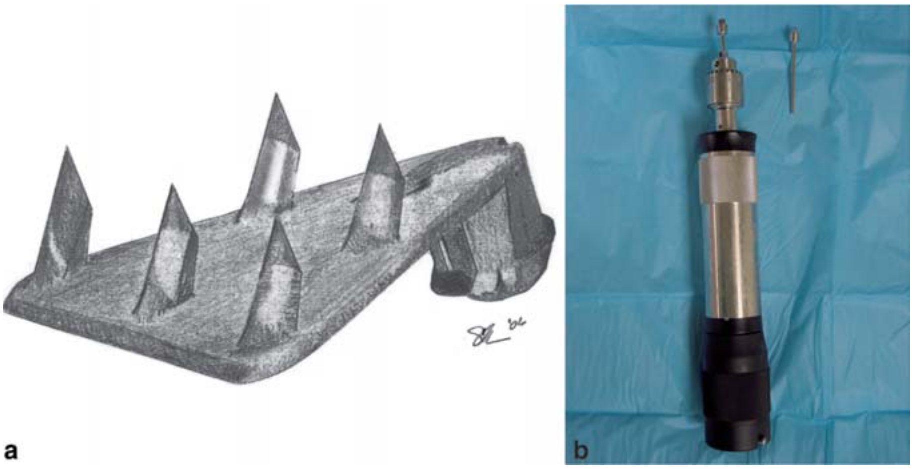


Fig. 8. The Endotine 3.5 Forehead device **(a)** with its 4-mm guarded drill bit **(b)**.

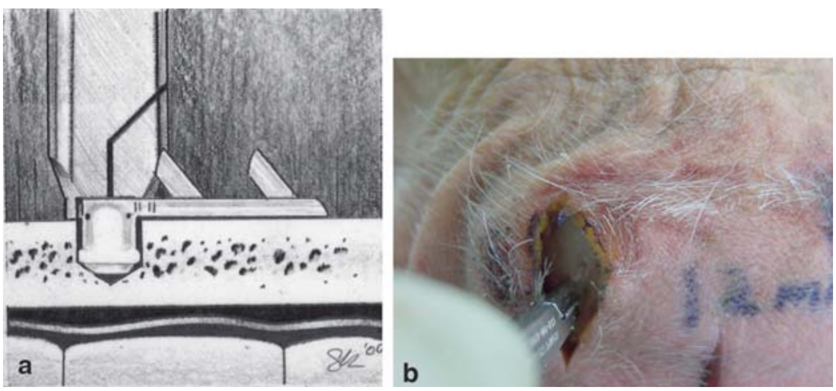


Fig. 9. Implant post seated in a pre-drilled hole **(a)**; scalp elevated to demonstrate placement **(b)**.

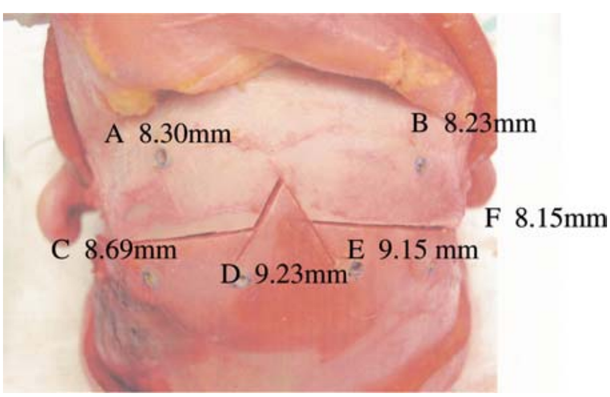


Fig. 10. Mean depth measurements at each site. Note that the thickest sites are posterior to the coronal suture and more medially oriented.

never penetrated the inner table in any of the 14 skulls. An example of a cortical tunnel can be seen in cross section (Fig. 11a), demonstrating that the tunnel actually is well away from the inner table. Mitek screws also never penetrated the inner table (Fig. 11b).

One Endotine implant post penetrated the inner table on the left side of one cadaver skull (Fig. 11c). The translucency can be noted on the left side of the midline (site A), which represents the implant post emerging through the inner table. Notably, this was the thinnest cranium measured, and it was 5.0 mm thick at the site of Endotine placement. After placement of 10-, 12-, and 14-mm miniscrews at each of the sites, it was found that one 12-mm and two 14-mm screws penetrated the inner table. The penetrations all were at far lateral sites (sites C and F) posterior to the coronal suture.

Discussion

The cranial vault functions as a protection for the brain and as a support structure for facial and masticatory functions. Previous studies have shown that the periosteal cortical plate (outer table) and the endosteal cortical plate (inner table) have significant differences in material properties. The outer table is thicker, denser, and stiffer than the inner table [14]. The current study focused on the thickness of the cranium at different sites commonly used for contemporary brow-lift procedures. We found the thickest area of the cranium in all the areas measured to be the parietal bone behind the coronal suture. Cranial bone thickness increases posteriorly and

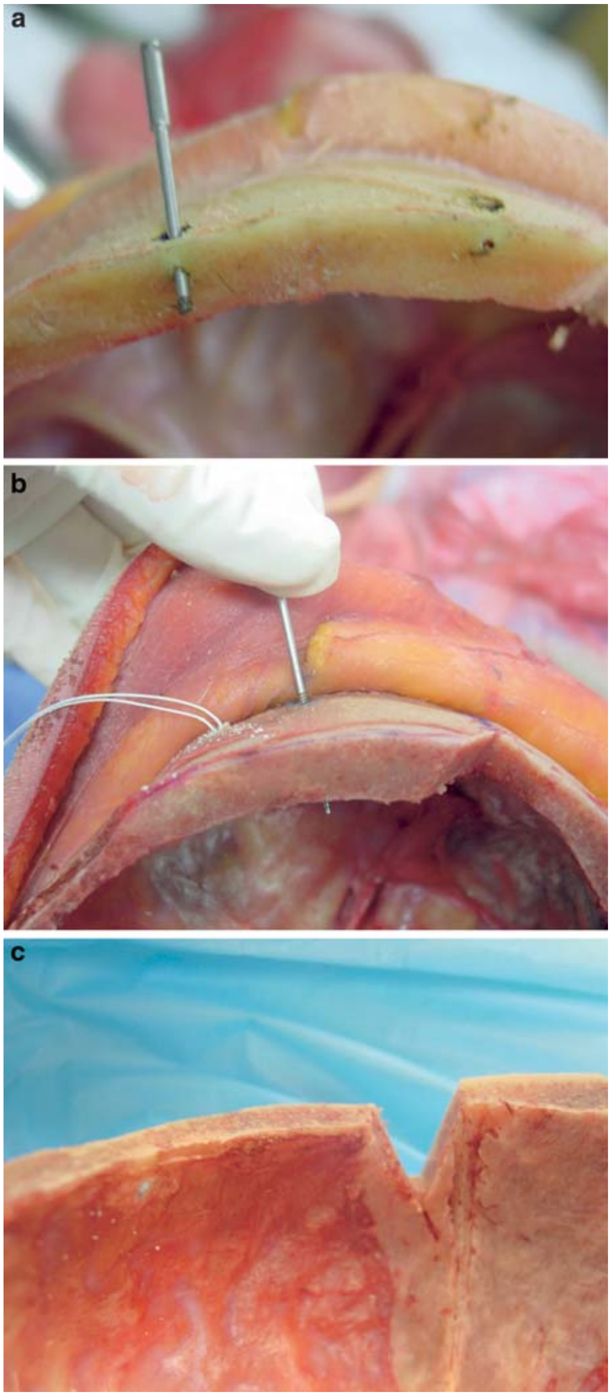


Fig. 11. Skull showing cortical tunnel made at a 45° angle, with aperture well away from the inner table **(a)**. Mitek screw shown within the skull and not penetrating the inner table **(b)**. Note the Endotine implant post penetrating the inner table to the left of the triangular osteotomy. The translucency here represents the post emerging through the inner table **(c)**.

medially, and women had thicker calvaria than men. The thickest calvarium was that of the only black male, and age was not a major variable in cranial bone thickness.

These results are similar to those of previous studies investigating cranial bone thickness [1,7,9,13,14,17,18]. In their cadaveric study of the calvarial donor site, Pensler and McCarthy [13] found that age and height had no statistical significance in the prediction of calvarial thickness. Weight, race, and sex were found to be the most important variables. There was a tendency for increased values as the measurements of skull thickness proceeded posteriorly, with the mean value for the entire population ranging from 6.80 to 7.72 mm at the various points examined. The merit of this study is its large sample size of cadaver skulls measured (n = 200) and the multiple regression analysis performed to determine which factors are significant in the determination of skull thickness.

In his series of cranial bone thickness measurements at selected points, Knize [8] showed that the posterior sites along the course of the middle meningeal artery were very thin (as thin as 2.1 mm). The anterior and far lateral sites of the temporal bone (sites that we did not measure) were found to be as thin as 1.7 mm. Diploic veins and venous lakes, or lacunae lateralis, also can erode areas of the inner table, and the thickness of the skull measured at these sites was found to be 3.404 mm.

In a study of skull thickness measured from radiographs of 300 blacks and 200 whites in America, Adeloye et al. [1] found that women had thicker parietal and occipital bones than men, and that the frontal bone tended to be thicker in the white male, with the parieto-occipital bone thicker in the black male. In both groups, the authors found a rapid increase in skull thickness during the first two decades of life, followed by a small uniform increase reaching a peak in the fifth and sixth decades. In one study, an increase in cranial thickness with age was observed in a series of 165 frontal and parietal bone specimens [17], and a study of skull thickness in black and white adults showed the white women to have the thickest and white men the thinnest skulls [18]. In a study of a modern Japanese population, the cranial thicknesses at the frontal and parietal eminences were significantly greater in the female than in the male [7].

In our study, one penetration of the inner table occurred with the Endotine device, and three with miniscrews. Relative contraindications of any invasive brow fixation technique include situations in which internal fixation is otherwise contraindicated by infection, a thin atrophic scalp, and as one manufacturer disclaimed, "patients appearing to have very thin bones which might imply inadequate cranial thickness" [12]. Of historical interest, in July 2003, Coapt Systems initiated a Food and Drug Administration (FDA) recall of the drill bit used with the Endotine device. The reason cited in the monthly FDA Enforcement report available to the public was that "during use, the device has a potential for unacceptable deep hole in the cranium which can cause patient injury" [5]. Notably, this was attribut-

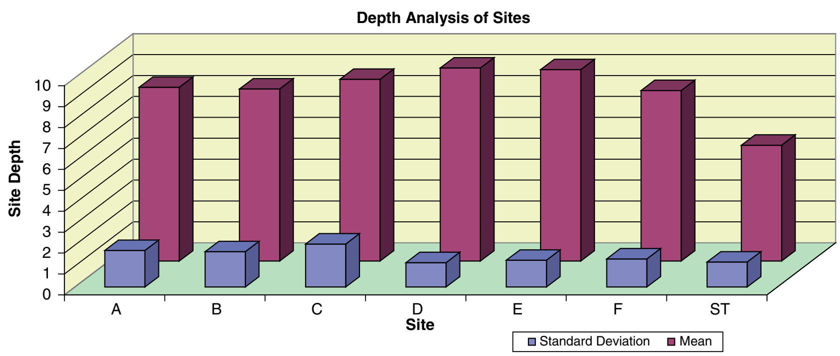
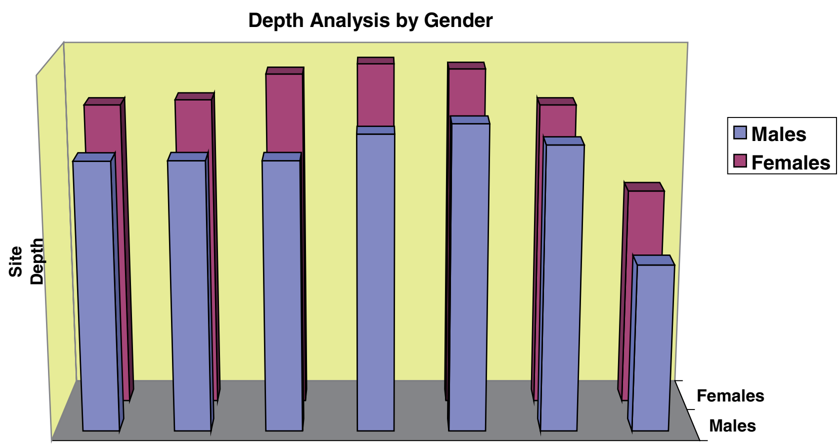


Fig. 12. Results of mean depth analysis by site for each cadaver shown in graphic form.



	Site						
Males	7.56	7.57	7.57	8.29	8.57	8	4.71
Females	8.57	8.71	9.43	9.71	9.57	8.57	6.14

Fig. 13. Mean depth of each site as stratified by gender. Note females had thicker skulls than males at all sites measured.

able to a failed stop collar, and the drill bit has since been revised to comprise a single piece [2]. The product currently is recommended only for patients with comparatively thick scalps (at least 5 to 6 mm), which places limitations on its use. Further short- and long-term studies with larger patient populations comparing other methods of fixation as controls are needed [4].

Other relative contraindications to invasive brow fixation of any sort include pathologic conditions of the bone including severe osteoporosis, cystic changes or hyperparathyroidism, Paget's disease, conditions such as osteopenia or osteomalacia, and osteonecrosis, which may result from radiation, corticosteroid use, previous fracture, or surgery. Of course, it also is prudent to avoid penetration of the sagittal sinus, as drill holes should not be made in the midline.

Given the aesthetic nature of brow-lift surgery, a cost analysis of the various brow fixation methods was performed. The cost of the Surgairtome Two gas-powered drill used for our cortical tunnels and/or for screw fixation is $1,500.00. The 3.0 PDS sutures used for fixation at the four posterior sites in a typical endoscopic brow-lift cost $4.20 each. Titanium miniscrews (Synthes Maxillofacial) cost $38 each, and usually are bought in a set of five. The Mitek Quickanchor system (including one screw with a disposable inserter and drill bit) costs $219.00 each. Each Endotine Forehead Device, or implant, costs $175.00, whereas the instrument kit for placement costs $600.00, and the manual surgical drill costs $895.00.

Conclusion

Variation in cranial bone thickness exists among specimens at different sites on the skull. In this study, the thickest area measured was found to be along the parietal bone behind the coronal suture, and thickness increased medially and posteriorly. Given unpublished reports describing inner table penetration with cerebrospinal fluid leak after invasive brow fixation techniques involving screw fixation, it behooves the surgeon to keep in mind the anatomy of the calvarium and its nuances just as one would for a reconstructive case involving harvest of a cranial bone graft.

It should be noted that the surgeon performing a cosmetic brow-lift usually does not have the luxury of a preoperative imaging study such as a computed tomography scan for assessing the thickness of the skull (as a potential donor site might be assessed before a split calvarial bone graft is taken). This should be all the more reason for thoughtfulness when any invasive brow fixation method is used. Notably, the results of a recent *in vivo* animal study suggest that A-mode ultrasound can accurately reflect cranial bone thickness, and that a portable, noninvasive ultrasonic device may be of some future clinical benefit in craniomaxillofacial surgery [3].

In summary, knowledge concerning the patterns of cranial bone thickness is helpful for safe brow fixation, and relative contraindications also may guide decision making before this aesthetic, and therefore purely elective, surgery.

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References

1. Adeloye A, Kattan KR, Silverman FN: Thickness of the normal skull in the American blacks and whites. *Am J Phys Anthropol* **43:**23–30, 1975
2. Apfelburg DB, Jacobs D: Coapt Systems Endotine technology for brow-lift. Letter to the editor. *Plast Reconstr Surg* **116:**336–337, 2005
3. Elahi MM, et al.: A new predictive modality of cranial bone thickness. *Ann Plast Surg* **42:**651–657, 1999
4. Evans GR, Shahrooz SBS, Ho K: Heads up on brow-lift with Coapt Systems' Endotine forehead technology. *Plast Reconstr Surg* **113:**1504–1505, 2004
5. FDA Enforcement Report, Food and Drug Administration, U.S. Department of Health and Human Services, July 30, 2003. Accessed www.fda.gov/bbs/topics/enforce/2003, 27th February 2005
6. Fiala T, Owsley J: Use of the Mitek fixation device in endoscopic brow-lifting. *Plast Reconstr Surg* **101:**1700, 1998
7. Ishida H, Dodo Y: Cranial thickness of modern and Neolithic populations in Japan. *Hum Biol* **62:**389–401, 1990
8. Knize DM: *The forehead and temporal fossa: Anatomy and technique*. 1st ed. Lippincott, Williams and Wilkins, Philadelphia, PA, 2001
9. Lynnerup N: Cranial thickness in relation to age, sex, and general body build in a Danish forensic sample. *Forensic Sci Int* **117:**45–51, 2001
10. Moore KL: *Clinically oriented anatomy*. 3rd ed. Williams and Wilkins. Baltimore, MD, pp 637–643, 1992
11. Ortiz-Monasterio F, Barrera G, Olmedo A: The coronal incision in rhytidectomy: The brow lift. *Clin Plast Surg* **5:**167, 1978
12. Package Insert, Endotine Forehead. Device instructions for use. Coapt Systems: Palo Alto CA, 2003. Accessed at www.coaptsystems.com 27th February 2005
13. Pensler J, McCarthy JG: The calvarial donor site: An anatomic study in cadavers. *Plast Reconstr Surg* **75:**648–651, 1985
14. Peterson J, Dechow PC: Material properties of the inner and outer cortical tables of the human parietal bone. *Anat Rec* **268:**7–15, 2002
15. Ramirez OM, Daniel RK: Endoforehead: Subperiosteal approach. In: *Endoscopic plastic surgery*. Springer-Verlag: New York, NY, pp. 46–65, 1995
16. Rohrich RJ, Beran SJ: Evolving fixation methods in endoscopically assisted forehead rejuvenation: Controversies and rationale. *Plast Reconstr Surg* **100(6):** 1575–1582, 1997
17. Ross AH, Jantz RL, McCormick WF: Cranial thickness in American females and males. *J Forensic Sci* **43:**267–272, 1998
18. Ross MD, Lee KA, Castle WM: Skull thickness of black and white races. *S. Afr. Med. J.* **50:**635–638, 1976
19. Stevens WG, Apfelberg MD, Stoker MD, Schantz SA: The Endotine: A new biodegradable fixation device for endoscopic forehead-lifts. *Aesth Surg* **23:**103–107, 2003
20. Swift RW, Nolan WB, Aston SJ, Basner AL: Endoscopic brow-lift: Objective results after 1 year. *Aesth Surg J* **19:**287, 1999