**Objectives:** To define the postoperative time interval required for elevated periosteum to readhere to the skull and regain its preoperative strength, and to evaluate whether fixation of the periosteum affects this interval or the strength of postoperative readhesion.

**Design:** Prospective analysis of variance and covariance with repeated measures.

**Subjects:** Thirty-six New Zealand white rabbits, each serving as its own control.

**Interventions:** Subperiosteal elevation was performed on one side of the skull, leaving the contralateral periosteum untouched. The periosteum in half of the subjects was lifted and fixed to a resorbable screw, with the comparison group undergoing subperiosteal elevation only, without lifting and fixation. Several adhesion characteristics were subsequently examined at postoperative weeks 1, 3, 5, 7, 8, 9, 10, 11, and 12. Half of the subjects were assessed histologically to determine attachment of periosteum onto underlying bone. The other half underwent analysis of periosteal readhesion strength.

**Results:** The 3 independent measures of periosteal adherence to the skull all lacked significant differences between sides after the first postoperative week. Blinded histologic analysis showed no evidence of ongoing periosteal healing and demonstrated no difference between operated-on and nonoperated-on sides. Analysis of periosteal stiffness ($P = .76$) and energy density ($P = .74$) also demonstrated no significant differences between sides.

**Conclusions:** Periosteal readhesion after surgical elevation is virtually complete by the seventh postoperative day. In addition, tension secondary to periosteal elevation with suspension has no influence on postoperative healing. These findings will contribute to the debate regarding the most appropriate brow-lift fixation technique.

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periosteum of the contralateral side remained untouched. The wound was copiously irrigated and suctioned. Closure was achieved in 2 layers with 4-0 polyglactin deep sutures and 4-0 gut reapproximating the skin edges.

At each of postoperative weeks 1, 3, 5, 7, 8, 9, 10, 11, and 12, 4 subjects were killed with barbiturate overdose. Two subjects underwent histologic analysis, 1 with periosteum affixed to the bioabsorbable screw under tension and 1 without, and 2 subjects underwent analysis with a hydraulic testing system (Materials Testing System; MTS Systems Corporation, Eden Prairie, Minn), also 1 with periosteum affixed to the bioabsorbable screw under tension and 1 without.

HISTOPATHOLOGIC ANALYSIS

The soft tissue layers of the scalp were dissected away and the top of the skull was removed with a bone saw. Bone-periosteum specimens (2 × 2 cm) were taken from both the operated-on and nonoperated-on sides with the superior border of the specimen lying along the midpupillary line. In this manner, the histologic specimens were taken from the corresponding area of the skull evaluated by statistical analysis in the remaining half of the subjects. Specimens were kept moist with isotonic sodium chloride solution until placed into formalin. The samples were sent to the Ochsner Clinic Department of Pathology, where they were prepared and examined by the same pathologist, who was blinded to both the postoperative time interval of the specimen and the presence of periosteal fixation to a screw.

Histopathologic analysis consisted of staining with hematoxylin-eosin and examination for evidence of healing: periosteal thickening or fibrosis, subperiosteal inflammation, or changes within adjacent adipose tissue or bone.

SHEAR STRENGTH ANALYSIS

The soft tissue layers of the scalp were removed and the top of the skull was separated with a bone saw. A surgical marker outlined the midpupillary and center lines. By use of a plastic template positioned just off the midline with its superior border along the midpupillary line, the periosteum was incised with an 11-blade scalpel. This was performed on both the operated-on and nonoperated-on sides. The bone posterior to the midpupillary line was then removed, leaving 2 strips of free periosteum. Two holes were drilled in the area of the nasion, each along the center line of the templated areas of periosteum (Figure 1). The entire skull cap was anchored to a stainless steel grip by a peg through the drilled hole. The periosteal strip was then affixed within a soft tissue grip attached to the testing machine. At all times the specimens were kept moist with isotonic sodium chloride solution.

By use of the hydraulic test frame of the testing system with integrated digital data acquisition, the periosteum was pulled in shear until it separated from the underlying skull (Figure 1). Shear force in newtons was recorded at 50-millisecond intervals until tissue failure occurred for each specimen. Shear stress (force per cross-sectional area [N/mm²]) was calculated by means of the shear force at each time point and the cross-sectional area of the surgical template.

The shear stress values for each specimen were used to calculate the 2 variables adopted for statistical analysis: shear stiffness and energy density. Stiffness, representing periosteal resistance to shear force, is defined as the slope of the linear portion of the stress vs time curve (derived from least-squares linear regression). Energy density, a relative measure of the energy required to pull the periosteum off of the skull, is defined as the area under the stress vs time curve (from time = 0 to specimen failure).

Analysis of variance and covariance with repeated measures was conducted for both stiffness and energy density, comparing the operated-on side with the nonoperated-on side across postoperative time intervals. In addition, screw-anchored specimens were compared with nonanchored specimens by means of the same analysis.

RESULTS

The 3 independent measures of periosteal adherence to the skull evaluated in this study—histologic tissue changes and periosteal attachment shear stiffness and energy density—all demonstrated no significant difference between operated-on and nonoperated-on sides after the first postoperative week, regardless of fixation under tension to a bioabsorbable screw.

All histologic samples were prepared and examined by the same pathologist, who was blinded to both the postoperative time interval of the specimen and the presence of periosteal fixation to a screw. All specimens, regardless of the postoperative time interval or fixation under tension, failed to demonstrate any significant differences.

Our examiner noted no evidence of progressive healing and thus was unable to differentiate between operated-on and nonoperated-on sides. This is exemplified in Figures 2, 3, and 4. There was no periosteal thickening or fibrosis, subperiosteal inflammation, or changes in adjacent adipose tissue. (The artifactual separation of periosteum from bone, present in both operated-on and nonoperated-on specimens, occurred during the bone-sectioning process.)

The lack of disparity among histologic specimens was mirrored by the values derived for both stiffness and energy density. The values calculated for shear stiffness, seen in Figure 5, ranged between $5.7 \times 10^4$ and $3.0 \times 10^5$ for nonoperated-on specimens and between $6.5 \times 10^4$ and $3.4 \times 10^5$ for operated-on specimens. Analysis of variance and covariance with repeated measures demonstrated no statistically significant difference ($P = .76$). The
The difference in means is far too small to be significant, as is the negligible divergence of SDs.

Analysis of the values calculated for energy density, seen in Figure 6, also lacked statistical significance ($P = .74$). These data points, which ranged between $3.2 \times 10^4$ and $3.5 \times 10^4$ for nonoperated-on specimens and between $5.9 \times 10^4$ and $5.6 \times 10^4$ for operated-on specimens, like-
Microscrews are used in many popular techniques. Sutures attached to underlying galea and/or periosteum may be anchored to miniscrews. The advantage of rigid fixation is a long-lasting lift of soft tissues.2 The disadvantages include patient reluctance to accept hardware, screws, or plates that are palpable and the possibility of intracranial placement. The advent of bioabsorbable screws has provided the option of rigid fixation without the undesired consequence of a long-term foreign body in the skull.3

A variation of rigid fixation is the creation of a bone bar from the skull itself. By use of a cutting burr at a 30° angle, a trough is formed in the outer cortex. The resulting tunnel provides a support point for the attachment of sutures, in the same manner as screws or plates. Advantages of this method include avoidance of external hardware, with their added cost, possibility of being palpable, and occasional need for removal. Disadvantages are the risk of disrupting emissary veins, possible intracranial extension, and difficulty of suture attachment.4

These last 2 disadvantages were addressed by Kobienia and Van Beek,5 who developed a U-shaped trough that they reported is technically easier to create than a cortical tunnel, facilitates suture attachment, and allows better visualization, which decreases risk of intracranial extension.

The plethora of available options for soft tissue fixation after brow-lift illustrates that the ideal technique remains unknown. The goal of this study was to clarify the time window required for tissue healing of sufficient magnitude to enable resistance to ptotic forces. This information will help define one criterion required of the ideal fixation technique—anchor strength with soft tissue stability able to provide long-term cosmetic results.

Our data suggest that the periosteum requires less than a week to readhere to the skull after subperiosteal elevation. This conclusion was corroborated by 3 variables—blinded histopathologic inspection of periosteal structural changes, together with biomechanical analysis rendering 2 independent measures of periosteal readhesion strength: periosteal stiffness and energy density.

The process of postoperative tissue healing is manifested histopathologically by the presence of periosteal thickening or fibrosis, subperiosteal inflammation, or changes in adjacent adipose tissue. In no subject were these changes noted. Every specimen, regardless of postoperative time interval or the presence or absence of periosteal tension, lacked a discernible difference between operated-on and nonoperated-on sides. We maintain that the absence of any difference is evidence of complete healing and achievement of periosteal readhesion.

The findings of the reparative process are well described, but the biomechanical analysis used in this study has not, to our knowledge, been previously reported. This method is validated by its strong statistical power—the capability to detect changes on the order of 50% of given values. Had healing not been complete, the energy density and periosteal stiffness would have been lower by orders of magnitude. This difference would therefore most certainly have been statistically significant.

It is common in tensile shear tests of biological soft tissue to observe wide variability in results, even among contralateral specimens. This variability may have masked our ability to detect differences between specimens that were mostly healed (ie, 75% reattached) and nonoperated-on specimens. However, our statistical analysis generated a power greater than 0.9 to detect a 2-fold difference between operated-on and nonoperated-on sides, so we are confident that any differences between slightly healed (ie, 23%) and nonoperated-on specimens would have been noted. As a result, we believe the data acquired in this study reflect testing of operated-on specimens that were mostly or completely healed.

This study found periosteal readhesion in the rabbit model to be virtually complete by the seventh postoperative day. Our group is currently preparing a follow-up study, including postoperative days 1 through 7, to further elucidate our understanding of the time required for tissue healing of sufficient magnitude to resist ptotic forces. We encourage future studies to aid in further advancing the evolving debate regarding the most appropriate brow-lift fixation technique.

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