Brow-Lift

Subgaleal vs Subperiosteal Flap Adherence in the Rabbit Model

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Objective: To analyze and compare the postoperative adherence qualities between the subperiosteal layer approach and the subgaleal layer approach for brow elevation using a rabbit model.

Methods: Twelve New Zealand white rabbits (weight, 3.1-3.5 kg) were evenly divided into 2 groups and underwent forehead flap elevation via subperiosteal or subgaleal dissection, depending on the group assignment. Two rabbits were not operated on and served as controls. Histologic and biomechanical testing (tensiometer) was performed at 2, 4, 6, 8, and 10 weeks to assess adherence and wound strength.

Results: The subgaleal flap strength was greater than that of the subperiosteal flap at each time point. The mean flap strength for the subgaleal and subperiosteal control subjects were 208 g and 706 g, respectively. These values approximately correspond with the postelevation subgaleal flap strength regained at 2 weeks and the postelevation subperiosteal flap strength regained at 8 weeks. On histologic analysis, the subgaleal specimen showed less intervening space and a greater degree of connective tissue proliferation than the subperiosteal specimen at as early as 4 weeks.

Conclusion: This study supports our hypothesis that rapid healing and early fixation occurs when the subgaleal approach is used for surgical brow elevation.

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The objective was to analyze and compare the postoperative adherence qualities between the subperiosteal layer approach and the subgaleal layer approach for brow elevation using a rabbit model. Twelve New Zealand white rabbits (weight, 3.1-3.5 kg) were evenly divided into 2 groups according to their respective planes of dissection. This particular species was chosen because it possesses many anatomic similarities to the human cranium, and previous research supports the New Zealand white rabbit as a useful model for preclinical brow-lift studies.

Of the 12 rabbits used in the study, 10 underwent surgical dissection, while the 2 remaining rabbits served as nonoperative controls.

SURGICAL TECHNIQUE

Each animal was anesthetized with an intramuscular injection of ketamine hydrochloride, 44 mg/kg plus xylazine, 4 mg/kg, solution and then intubated, positioned ventrally, and draped in a sterile fashion. A prophylactic dose of the antibiotic enrofloxacin, 5 mg/kg, was given prior to surgery.

Lidocaine hydrochloride with 1:100 000 epinephrine was infiltrated into the subcutaneous tissue along the planned incision site. A horizontal incision was made just posterior to the orbital rims using a No. 15 blade. A soft tissue flap was subsequently elevated in a subperiosteal or subgaleal plane, depending on the group assignment (Figure 1 and Figure 2). The area of dissection was standardized in each specimen. The flap was elevated out to each orbital rim laterally and 4 cm caudal to the incision. To reproduce the caudally vectored tension expected following a brow-lift procedure, the flap was repositioned superiorly, and any redundant soft tissue was excised (Figure 3). This allowed wound closure under what we referred to as “clinical tension” and thereby helped to better reflect the wound characteristics produced after a brow-lift procedure. The deep layer (galea vs periosteum) was reapproximated using 4-0 Vicryl (Ethicon, Somerville, NJ) interrupted sutures, and the skin was closed using 5-0 interrupted Prolene sutures (Ethicon). Postoperatively, subcutaneous buprenorphine hydrochloride, 0.01 mg/kg, was administered for analgesia, and subjects were monitored daily for signs of infection or wound dehiscence.

Biomechanical strength and histologic adherence were compared at 2-week intervals during the postoperative period. A single subject was chosen from each group and killed using sodium pentobarbital at 2, 4, 6, 8, and 10 weeks postoperatively. The cranium and overlying soft tissue corresponding to the area of dissection was isolated using a sagittal saw. The isolated cranial segment was then divided down the midline, and histologic analysis was performed on one half and biomechanical strength testing on the contralateral side (Figure 4).
BIOMECHANICAL STRENGTH

A tensiometer (Instron 4301; Instron Corp, Norwood, Mass) was used to measure flap strength by determining the force required to separate the previously dissected flap from its respective underlying tissue. After securing the harvested bone–soft tissue segment within the device, crossheads were attached to the soft tissue flap. A progressive force was then applied until the flap was completely avulsed (Figure 5). Maximum biomechanical strength was recorded in grams. The flap area was divided into equal sections, allowing 2 strength measurements from each rabbit.

HISTOLOGIC ANALYSIS

The contralateral side was immediately fixed in a 10% formalin solution and subsequently placed into a 5% nitric acid solution to decalcify the attached bone. The tissue was then embedded in paraffin, sectioned, and stained using hematoxylin–eosin. Slide preparations of the tissue were microscopically examined for flap adherence at each time point using magnifications of ×20 and ×40.

RESULTS

BIOMECHANICAL STRENGTH

The mean avulsion force required to separate the previously elevated flap at each time interval is displayed summarized in the Table and illustrated in Figure 6. At each time point, the subgaleal flap strength was greater than that of the subperiosteal flap. An unexpected drop in strength was seen between the fourth and sixth weeks in both groups, with a greater decrease in strength in the subperiosteal category. The cause for this is unclear; however, it is likely secondary to shear forces introduced by the sagittal saw during the sectioning process.

The mean flap strength for the subgaleal and subperiosteal control subjects was 208 g and 706 g, respectively. In other words, in rabbits that had not previously undergone surgical flap elevation, 208 g of force was required to separate the galea from the underlying perios- teum, and 706 g of force to separate perioisteum from under- derlying bone. When compared with the flap strength after surgical elevation, these values approximately corresponded with the postelevation subgaleal flap strength regained at 2 weeks and the postelevation subperiosteal flap strength regained at 8 weeks (Figure 6).

HISTOLOGIC ANALYSIS

The prepared histologic slides were examined for the degree of intervening space between tissue layers and for the proliferation of connective tissue after soft tissue elevation. A difference in the degree of readherence between the 2 groups was evident as early as 4 weeks into the postoperative period. Photomicrographs at 2 weeks and 4 weeks are shown in Figure 7. At 2 weeks, both the subperiosteal and subgaleal groups show near complete discontinuity from their respective deeper tissue planes, with a significant degree of intervening space and minimal connective tissue proliferation. At 4 weeks, however, the subgaleal specimen shows less intervening space and a greater degree of connective tissue proliferation compared with the subperiosteal specimen.

It should be noted that a degree of separation artifact can be introduced during histologic preparation. Prior to staining, each specimen underwent an extensive decalcification process using a 5% nitric acid solution and was subsequently embedded in paraffin. These steps introduce the possibility for handling and mechanical trauma, which may lead to separation artifact.
The aging process of the face is primarily a soft tissue phenomenon, with a decrease in elasticity and tone leading to ptosis of the forehead structures. As a result of this creep phenomenon, the skin moves inferiorly over a fixed periosteum.² The technique of replacing the aging brow into a more youthful position by repositioning the soft tissues of the forehead would appear to be a physiologically sound method. This is precisely what is done with the subgaleal brow-lift procedure. Our results appear to indicate that the subgaleal dissection, in addition to being the most direct way of correcting brow ptosis, may afford more rapid healing, more rapid fixation to underlying structures, and improved flap strength compared with the subperiosteal dissection.

As in Romo et al.,¹³ our study showed that the subperiosteal dissection healed in about 8 weeks, when the biomechanical strength of the flap in the surgical rabbits was compared with the control rabbits. The subgaleal group in our study reached the strength of the control much sooner than that of the subperiosteal group. We found that the force required to avulse the flap was equal to the control at about the 2-week point. This result supports our hypothesis that soft tissue to soft tissue healing would occur more rapidly than soft tissue to bone. Early histologic results also seem to corroborate our hypothesis.

We found a very interesting trend in the avulsion force of the subgaleal group as healing progressed over the 10 weeks. The strength of the flap continued to increase significantly over time, and every rabbit tested was stronger than its corresponding rabbit in the subperiosteal group. In fact, we did not see a plateau in the strength. The 10-week specimen was nearly 5 times stronger than that of the control rabbit. These results were tested multiple times per specimen with similar results each time.

Our results do not seem to be a product of testing, mechanical, or sampling error because the trend of increasing strength continued through all of the rabbits tested. These rabbits were tested at multiple time periods, and each test was repeated per rabbit. In addition, the results in the subperiosteal group showed a similar trend, which corresponded very closely with the results obtained by a number of other researchers.¹³⁻¹⁵

The significant increase in strength could be accounted for by developing fibrosis between the galeal and periosteal layers. We saw this in the early histologic sections obtained from subgaleal dissection subjects. Clinically, the excess scarring and fibrosis encountered during revision surgery also supported this phenomenon.

If the results of our study can be translated to humans, the subgaleal dissection may afford better flap strength and therefore be less prone to recurrence of brow ptosis. In addition to the superior strength, the rapid healing seen in the subgaleal group would have implications on the choice of brow fixation methods. A temporary, short-lasting method would be all that is necessary for a stable brow elevation. New materials could be developed that could fixate the brow flap and be degraded or resorbed after only several weeks. This could improve patient comfort and possibly lower the risk for infection or extrusion.

Nevertheless, the healing process in the rabbit could be very different than that in a human. Scarring might be more abundant and/or robust in the rabbit model, and thus, the intense fibrosis might account for the increased strength that we found. Because our study appears to be one of the first to look at the healing properties in the subgaleal approach, we do not have any other studies with which to compare our results. With future research, we might find that this type of healing occurs between soft tissue layers but only in the rabbit model. If that is the case, then the rabbit is not an appropriate model for evaluating the subgaleal approach and another model will need to be found. More studies to evaluate the subgaleal approach will be of interest.

In conclusion, this study supports our hypothesis that rapid healing occurs when the subgaleal approach is used in the brow-lift procedure. The flap also exhibits excellent strength, which we have seen clinically in our experience with the subgaleal endoscopic brow-lift. The recovery rate in our patients is rapid, and the results are...
long lasting. This technique, in our opinion, is the optimal approach for most patients and has been the primary technique used by one of us (J.R.T.) with excellent and predictable results.

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