Cosmetic

Biomechanical and Viscoelastic Properties of Skin, SMAS, and Composite Flaps as They Pertain to Rhytidectomy

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Previous studies have focused on biomechanical and viscoelastic properties of the superficial musculoaponeurotic system (SMAS) flap and the skin flap lifted in traditional rhytidectomy procedures. The authors compared these two layers with the composite rhytidectomy flap to explain their clinical observations that the composite dissection allows greater tension and lateral pull to be placed on the facial and cervical flaps, with less long-term stress-relaxation and tissue creep. Eight fresh cadavers were dissected by elevating flaps on one side of the face and neck as skin and SMAS flaps and on the other side as a standard composite rhytidectomy flap. The tissue samples were tested for breaking strength, tissue tearing force, stress-relaxation, and tissue creep. For breaking strength, uniform samples were pulled at a rate of 1 inch per minute, and the stress required to rupture the tissues was measured. Tissue tearing force was measured by attaching a 3-0 suture to the tissues and pulling at the same rate as that used for breaking strength. The force required to tear the suture out of the tissues was then measured. Stress-relaxation was assessed by tensing the uniformly sized strips of tissue to 80 percent of their breaking strength, and the amount of tissue relaxation was measured at 1-minute intervals for a total of 5 minutes. This measurement is expressed as the percentage of tissue relaxation per minute. Tissue creep was assessed by using a 3-0 suture and calibrated pressure gauge attached to the facial flaps. The constant tension applied to the flaps was 80 percent of the tissue tearing force. The distance crept was measured in millimeters after 2 and 3 minutes of constant tension. Breaking strength measurements demonstrated significantly greater breaking strength of skin and composite flaps as compared with SMAS flaps ($p < 0.05$). No significant difference was noted between skin and composite flaps. However, tissue tearing force demonstrated that the composite flaps were able to withstand a significantly greater force as compared with both skin and SMAS flaps ($p < 0.05$). Stress-relaxation analysis revealed the skin flaps to have the highest degree of stress-relaxation over each of five 1-minute intervals. In contrast, the SMAS and composite flaps demonstrated a significantly lower degree of stress-relaxation over the five 1-minute intervals ($p < 0.05$). There was no difference noted between the SMAS flaps and composite flaps with regard to stress-relaxation. Tissue creep correlated with the stress-relaxation data. The skin flaps demonstrated the greatest degree of tissue creep, which was significantly greater than that noted for the SMAS flaps or composite flaps ($p < 0.05$). Comparison of facial flaps with cervical flaps revealed that cervical skin, SMAS, and composite flaps tolerated significantly greater tissue tearing forces and demonstrated significantly greater tissue creep as compared with facial skin, SMAS, and composite flaps ($p < 0.05$). These biomechanical studies on facial and cervical rhytidectomy flaps indicate that the skin and composite flaps are substantially stronger than the SMAS flap, allowing significantly greater tension to be applied for repositioning of the flap and surrounding subcutaneous tissues. The authors confirmed that the SMAS layer exhibits significantly less stress-relaxation and creep as compared with the skin flap, a property that has led aesthetic surgeons to incorporate the SMAS into the face lift procedure. On the basis of the authors' findings in this study, it seems that that composite flap, although composed of both the skin and SMAS, acquires the viscoelastic properties of the SMAS layer, demonstrating significantly less stress-relaxation and tissue creep as compared with the skin flap. This finding may play a role in maintaining long-term results after rhytidectomy. In addition, it is noteworthy that the cervical flaps, despite their increased strength, demonstrate significantly greater tissue creep as compared with facial flaps, suggesting earlier relaxation of the neck as compared with the face after rhytidectomy. (*Plast. Reconstr. Surg.* 110: 590, 2002.)

Since the description of the superficial musculoaponeurotic system (SMAS) layer by Skoog[1] in 1974, its manipulation has become a standard part of the rhytidectomy procedure. The methods used to incorporate the SMAS flap into the procedure are variable, with the

majority of facial aesthetic surgeons performing the SMAS technique as a two-layer lift, as first described by Mitz and Peyronie[2] in 1976. This two-layer procedure, in contrast to the single-layer or deep-plane rhytidectomy described by Hamra[3] in 1992, has the advantage of allowing manipulation of the subcutaneous and SMAS layers in different directions with different degrees of tension.[4]

After Furnas[5] recognized the importance of the retaining ligaments, several researchers adapted an extended SMAS dissection extending medial to the ligaments.[6–9] The extended dissection allows mobilization of the SMAS and overlying subcutaneous fat medially, which results in a more complete rejuvenation of the midface and jowls. However, proponents of the deep plane or composite rhytidectomy believe that lifting the aging face below the SMAS layer results in improved vascularity in the composite flap as compared with the skin when dissected separately from the SMAS.[2,10,11] This is thought to allow one to place significantly greater tension on the composite flap without concern for preauricular or postauricular skin necrosis.

In the cervical region, most investigators, regardless of their technique superior to the mandibular border, limit their dissection to the plane superficial to the platysma and rely heavily on medial plication of the platysma to achieve cervical rejuvenation.[12–15] Owsley[16] does an extensive dissection deep to the platysma, extending medially to the midline. However, an alternative, "composite" type of dissection has been advocated in which the platysma is not separated from the skin, the dissection is limited laterally, and cervical rejuvenation is achieved by strong lateral tension.[17] The senior author (T.A.M.) modified this technique with mobilization extended to the lateral edge of the platysma, the submandibular gland region beyond the lateral platysmal deeper attachments in the region of the mandibular border, and the region defined by the inferomedial extent of the parotid. This dissection permits adequate cervical mobilization yet with a high degree of safety. The marginal mandibular and cervical branches of the facial nerve are not put at significant risk, and they retain the advantages of strength and vascularity of the composite flap.

In the senior author's 12-year experience with the composite flap rhytidectomy, the ability to place a higher degree of tension on composite flaps as compared with subcutaneous or SMAS flaps facilitates repositioning of the descended facial subcutaneous landmarks to their original locations. Furthermore, correction of cervical laxity without the need for a submental incision and dissection is possible in the majority of patients. This is accomplished by applying a high degree of cephalad tension on raised composite flaps in a vector perpendicular to the obtuse angle of the aging submentocervical angle.

In this study, we aimed to scientifically evaluate any differences in quasi-static tissue breaking strength and viscoelastic stress-relaxation and creep between the three layers used in various types of rhytidectomy procedures: the skin-subcutaneous flap, the SMAS flap, and the composite flap. We proposed that the biomechanical and viscoelastic differences between these flaps would support and explain our clinical observations that the composite flap allows greater tension and lateral pull to be placed on the facial flaps, with less long-term relaxation, which may have advantages in most patients.

In previous studies, Har-Shai et al.[18,19] focused on the biomechanical and viscoelastic differences between the skin-subcutaneous and SMAS layers, demonstrating significantly less stress-relaxation and creep in the SMAS tissues. On the basis of this work, Rubin et al.[20] created a constitutive model capable of predicting the highly nonlinear elastic and rate-dependent inelastic responses of the skin-subcutaneous and SMAS tissues of the face. These authors concluded that the SMAS is the firmer elastic foundation of the more viscous skin and that the skin would be expected to conform to the deformation of the SMAS if it remained attached to the SMAS during stretching. Although these studies indirectly suggest a physiologic benefit to maintaining the attachments of the skin to the SMAS layer, this has not been investigated directly. In an attempt to more directly address this issue, in this study, the properties of the skin-subcutaneous and SMAS layers are compared with those of a composite layer consisting of the two layers still attached.

MATERIALS AND METHODS

Surgical Technique

Eight fresh cadavers were used for this study. The cadavers were obtained from the Anatomical Gift Association within 72 hours of death and were dissected immediately. The ages

ranged from 53 to 84 years, with an average age of 69 years. Causes of death were aspiration pneumonia,[3] cardiopulmonary arrest,[2] pulmonary embolism,[1] lung cancer,[1] and laryngeal cancer.[1] Smoking status or prior chronic steroid use was unknown. In all cadavers, at random, one side of the face was lifted as a composite rhytidectomy as described by Hamra,[3] and the other side was lifted as a subcutaneous rhytidectomy with separate elevation of the SMAS layer. The cervical area was dissected with the platysmal extension of the SMAS layer in the face. Hence, the cervical composite flap consisted of the platysma, subcutaneous tissue, and skin, whereas the SMAS flap consisted of just the platysma and its investing fascia. The medial extent of the facial dissection was a line connecting points located 1 cm lateral to the nasolabial fold and 1 cm lateral to the oral commissure, directed in a perpendicular fashion to the inferior edge of the mandible. The medial extent of the cervical dissection was to the medial border of the submandibular gland.

Evaluation of Breaking Strength and Tearing Force

After composite, subcutaneous, and SMAS flap elevation, the flaps were excised from five cadavers, and an Instron Universal Tester (Model 1114, Canton, Mass.) was used to assess tissue breaking strength in two ways. The first method consisted of stretching a tissue sample of a known cross-sectional area between two Instron grips until the sample ruptured in the center. This method will be referred to as the tissue breaking strength. The second method, thought to be more clinically relevant, involved placing a 3-0 suture into the tissue samples in the same manner as for flap fixation purposes during rhytidectomy, and using the Instron to pull the 3-0 suture out of the sample. This method will be referred to as the 3-0 suture tearing force.

For tissue breaking strength, each flap type was cut into multiple samples ($n = 20$ for each flap type, four samples from each cadaver). Using a razor blade template cutter in a dumbbell-shaped form, the samples were cut into strips with a minimal width of 0.12 inch (3.0 mm) at the center and a maximal width of 0.24 inch (6.0 mm) at the ends. The dumbbell shape was used to ensure that the samples would break in the center. The length of the strips was 0.39 inch (10 mm). The thickness of each sample was measured with a dial gauge (Federal Products, Providence, R.I.; 0.001 inch

per division, Model 3-C100-1000). The thickness of the samples ranged from 0.02 to 0.11 inch. The strips were then placed in the serrated Instron gripping devices and were pulled at a rate of 1 inch per minute or 2.54 cm per minute by the Instron, and the forces required to rupture the tissues were measured. Breaking strength, or the stress required to rupture the tissues, is calculated as force (in pounds or newtons) divided by the tissue width and thickness (inches or millimeters). This value is then represented as pounds per square inch in the English system or as megapascals when using the metric system.

For 3-0 suture tearing force, multiple samples ($n = 20$ for each flap type, four samples from each cadaver) were cut into 0.20-inch-wide (5 mm) and 0.39-inch-long (10 mm) strips by using a constant template cutter. A 3-0 suture on a noncutting needle was placed through the SMAS flap. For the subcutaneous and composite flaps, the 3-0 suture, again on a noncutting needle, was placed through the subcutaneous tissues with or without the SMAS and the deep layer of dermis, but not through the epidermis. The end of the 3-0 suture was secured to a Capstan grip, and the tissue was secured in a serrated clamp. The grips were pulled apart at a rate of 1 inch per minute or 2.54 cm per minute. The force (pounds or newtons) required to tear the suture out of the tissue sample was recorded.

Stress-relaxation

Definition. Tissue stress-relaxation is measured by initially applying a fixed amount of tension that results in a certain degree of tissue deformation or elongation, which is held constant for a period of time, after which, the tension within the tissue is measured. The decrease in tissue tension during this time period represents the stress-relaxation of the tissue.

Evaluation. After composite, subcutaneous, and SMAS elevation, the flaps were excised from five cadavers, and an Instron Universal tester was used to assess tissue stress-relaxation. Multiple samples ($n = 30$ for each flap type, six samples from each cadaver) were cut using the dumbbell-shaped template described for breaking strength testing above. These samples were placed in the Instron serrated grips. Using the value of the average breaking strength obtained from the tissue breaking strength experiment for each tissue type, the three types of tissues were tensed to 80 percent of their tissue break-

ing strength at a rate of 1 inch per minute or 25.4 mm per minute. The amount of tissue deformation was kept constant for 1 minute, allowing stress-relaxation to occur. The decrease in tension within the tissue sample was recorded as a stress-relaxation curve by the Instron chart recorder running at 1 inch per minute. After the 1-minute period, the same tissue sample was tensed again to 80 percent of its tissue breaking strength. Again, the degree of tissue deformation was kept constant for 1 minute, and the decrease in tension within the tissue sample was recorded. The samples were tensed for a total of five times to 80 percent of that particular sample's tissue breaking strength. Tissue deformation, as a result of the tensing force, was kept constant for 1-minute intervals, during which the amount of tissue stress-relaxation was recorded. The degree of tissue stress-relaxation is represented as the percentage decrease in tissue tension during the 1-minute periods. These observations at the five different time periods are dependent of one another because the same sample was used.

Creep

Definition. Measuring tissue creep consists of applying a constant amount of tension or load on the tissue and measuring the amount of tissue deformation that occurs over a period of time. Hence, creep is described as the tissue deformation per given length of time at a constant load.

Evaluation. Four cadavers were used to measure creep of the differing flap types ($n = 4$ for each flap type, one sample from each cadaver). Cadavers underwent composite or standard subcutaneous rhytidectomy with SMAS elevation on one or another side of the face at random. Dissections were carried medially to the endpoints mentioned earlier in an equidistant fashion to create facial and cervical flaps that were as identical as possible on both sides. The medial limit to the cervical flaps was approximately the medial edge of the submandibular gland.

We placed 3-0 sutures in the facial and cervical flaps. On the composite side, a single suture, placed in the facial composite flap at a point that would come to lie over the preauricular area if pulled, was tacked down as in a rhytidectomy procedure. Another suture was placed in the cervical composite flap at a point that would come to lie over the mastoid process if pulled and tacked down. On the side

opposite from where the subcutaneous and SMAS flaps had been elevated, sutures were placed in both flaps in locations matching those of the composite sutures in both the facial and cervical locations. In the composite and skin flaps, sutures were placed into the deeper layer of the dermis, but not through the epidermis, as would be done when tacking down flaps during a rhytidectomy.

We used 3-0 sutures because (1) their measured breaking force (21.5 ± 2.4 pounds or 95.6 ± 10.7 newtons) was greater than any applied tension required for our creep measurements, (2) surgeons are unlikely to place greater than 21.5 pounds of tension on an elevated rhytidectomy flap because the suture has a high likelihood of rupturing through the tissue, (3) surgeons are unlikely to use a thicker suture in tacking down rhytidectomy flaps for fear of creating tension that would compromise tissue vascularity, and (4) the senior author uses this suture under a similar degree of tension clinically when performing composite flap rhytidectomies.

With an assistant to stabilize the cadaver head, a calibrated force gauge (Omega Digital Force Gauge DFG51, Stamford, Conn.) was used to apply the appropriate amount of tension in a cephalad-posterior direction, identical to the direction pulled during fixation of the layers to underlying tissue in a rhytidectomy. The amount of tension used was 80 percent of the tissue's 3-0 suture tearing force as identified earlier. The tension was held constant for a total of 3 minutes by using a pressure gauge. The distance that the anchoring point of the 3-0 suture moved was measured at 2 and 3 minutes while applying constant tension on the 3-0 suture.

Statistical Analysis

Statistical analyses of intergroup comparisons were performed using Student's *t* test and a one-way analysis of variance with post hoc analysis using the Newman-Keuls test for between groups. Significance was accepted for a *p* value of <0.05 or 0.001 where noted. Comparisons were made between the three different flap types with regard to breaking strength, 3-0 Vicryl tearing strength, stress-relaxation, or tissue creep.

Statistical analysis was also performed by taking into account the age of the cadavers. Two groups, one 65 years or younger (young group) and the other older than 65 years (old

group) were compared to determine if age had an impact on flap type breaking strength, 3-0 suture tearing strength, stress-relaxation, or tissue creep. A two-way analysis of variance with post hoc analysis using the Newman-Keuls test for between groups was used, with significance accepted for a p value of <0.05.

RESULTS

Breaking Strength

The breaking strength of the skin, SMAS, and composite flaps was measured in two ways, as described above. Using the tissue breaking strength method, a significant difference in breaking strength was noted between the SMAS flap and both the skin and composite flaps. No difference was noted between the skin flap and the composite flap, for a p value <0.05 (Fig. 1, *above*).

With the 3-0 suture tearing force method, the SMAS flap was able to withstand significantly less force as compared with both the skin and composite flaps. However, in contrast to the tissue breaking strength data, the com-

posite flap exhibited a significantly greater 3-0 suture tearing force as compared with the skin flap ($p < 0.05$ for all values) (Fig. 1, *below*).

Stress-relaxation

The skin flap exhibited the highest degree of stress-relaxation at all five 1-minute stress-relaxation intervals. The difference was statistically significant for all time points as compared with both the SMAS flap and the composite flap. There was no significant difference in stress-relaxation noted between the SMAS flap and the composite flap after one, two, three, four, or five applications of tension. Our data consistently revealed a 50 ± 5 percent stress-relaxation in skin flap tissues within the first minute after tensing the tissue to 80 percent of its tissue breaking strength. After four additional increases in tension to 80 percent of its tissue breaking strength, the skin layer still exhibited 40 ± 10 percent stress-relaxation during the final 1-minute interval.

In contrast, the SMAS flap and composite flap demonstrated significantly less stress-relaxation as compared with the skin when tensed to 80 percent of their respective tissue breaking strengths at all five 1-minute intervals. There was no significant difference in stress-relaxation rates noted between the SMAS flap and the composite flap (Fig. 2, *above*).

Creep

Measurements of tissue creep taken at 2 and 3 minutes while constant tension was applied to the flap seem to correlate with the stress-relaxation findings. The skin flap exhibited greater than twice the amount of creep at both 2 and 3 minutes as the SMAS flap and the composite flap (Fig. 2, *below*). There was no significant difference in creep noted between the SMAS flap and composite flap.

Comparisons between Facial and Cervical Tissue

Student's t test was used for statistical analysis to identify any differences between the biomechanical properties of facial and cervical tissue. The results were dependent on the testing technique used. Interestingly, significant differences between facial and cervical skin were noted in the experiments involving the use of the 3-0 suture, with the cervical skin, SMAS, and composite flaps consistently exhibiting significantly higher 3-0 suture tearing forces as compared with their respective facial flaps ($p < 0.001$) (Fig. 3, *above*). Creep measurements,
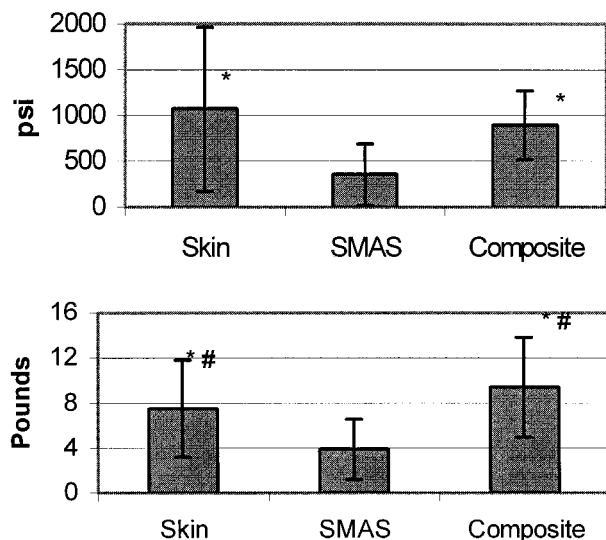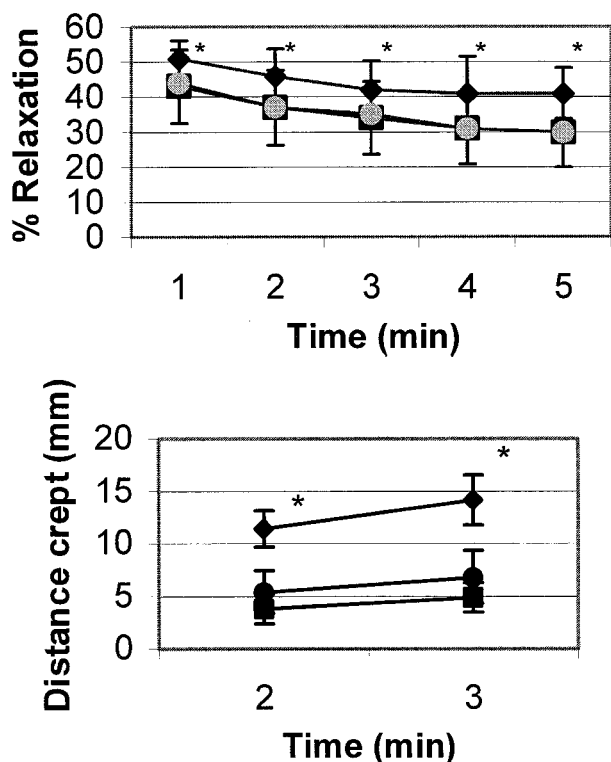

FIG. 1. (*Above*) Tissue breaking strength. The skin and composite flaps demonstrated significantly greater tissue breaking strength as compared with the SMAS flap. No significant difference was noted between the skin and composite flaps ($n = 20$ for each flap type taken from five cadavers). *psi*, pounds per square inch. *T-bars* indicate SDs. *, significantly greater than SMAS for $p < 0.05$. (*Below*) 3-0 Vicryl tearing force. Note that both skin and composite flap 3-0 suture tearing forces were significantly greater as compared with the SMAS flap. In addition, the composite flap tolerated significantly greater 3-0 suture tearing force as compared with the skin flap ($n = 20$ for each flap type taken from five cadavers). *T-Bars* indicate SDs. *, significantly greater than SMAS for $p < 0.05$; #, significant difference for $p < 0.05$.

FIG. 2. (*Above*) Stress-relaxation. Note the significantly higher stress-relaxation of the skin flap at all time points as compared with both the SMAS and composite flaps. No significant difference in stress-relaxation was noted between the SMAS and composite flaps at any time point (*n* = 30 for each flap type taken from five cadavers). *T-Bars* indicate standard deviations. *, *p* < 0.05 as compared with SMAS and composite flaps; *diamond*, skin flap; *square*, SMAS flap; *shaded circle*, composite flap. (*Below*) Tissue creep measurements. Note that the skin flap demonstrated twice the amount of tissue creep as the SMAS and composite flaps. No significant difference was noted between the SMAS and composite flap tissue creep (*n* = 4 for each flap type taken from four cadavers). *T-Bars* indicate standard deviations. *, *p* < 0.05 as compared with SMAS and composite flaps; *diamond*, skin flap; *square*, SMAS flap; *circle*, composite flap.

also undertaken by placing a 3-0 suture into the flaps and applying tension, revealed significantly higher values for cervical skin and composite flaps as compared with facial skin and composite flaps (*p* < 0.001) (Fig. 3, *below*).

These data demonstrate that although cervical flaps composed of skin, SMAS, or composite tissues are able to withstand significantly greater degrees of tension before tearing as compared with their respective facial flaps, they also demonstrate a greater degree of tissue creep as compared with their respective facial flaps. This accelerated tissue deformation over a fixed period of time in cervical tissues as compared with facial tissue implies

that cervical tissues relax faster than facial tissues over a given period of time.

Age

The age of the cadavers ranged from 53 to 84 years, with an average age of 69 years. Four cadavers were 65 years or younger and constituted the young group. The other four cadavers were older than 65 years and constituted the old group. A two-way analysis of variance was used to compare the four parameters of tissue breaking strength, 3-0 suture tearing force, tissue stress-relaxation, and tissue creep in the two age groups.

Tissue breaking strength was significantly lower in the old group (*n* = three cadavers, 36 samples) as compared with the young group (*n* = two cadavers, 24 samples; *p* < 0.05). This was the case for all three flap types: skin, SMAS,
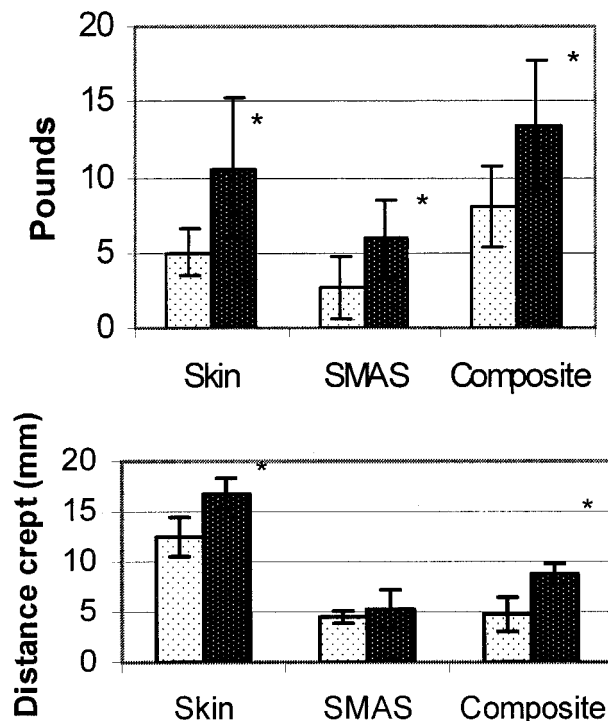

FIG. 3. (*Above*) 3-0 Vicryl tearing strength: facial versus cervical flaps. Note the significantly greater 3-0 suture tearing strength of the cervical flaps as compared with the facial flaps (*n* = 20 for each flap type; *n* = 30 for facial skin; *n* = 30 for cervical skin). *T-bars* indicate SDs. *, significantly greater than facial flaps for *p* < 0.05; *open bars*, facial; *solid bars*, cervical. (*Below*) Tissue creep at 3 minutes: facial versus cervical flaps. Note the significantly greater tissue creep in the cervical skin and composite flaps as compared with the facial skin and composite flaps. No significant difference in tissue creep was appreciated between the cervical and facial SMAS (*n* = 20 for each flap type; *n* = 30 for facial skin; *n* = 30 for cervical skin). *T-Bars* indicate SDs. *, significantly greater than facial flaps for *p* < 0.05; *open bars*, facial flap; *solid bars*, cervical flap.

and composite. When analyzed by age, the young group demonstrated significant differences between composite, skin, and SMAS flap type tissue breaking strengths in decreasing order ($p < 0.05$ for all comparisons), and the old group demonstrated significant differences only between the SMAS and composite flaps (Fig. 4, *above*).

Overall, 3-0 suture tearing force was significantly lower in the old group (n = three cadavers, 36 samples) as compared with the young group (n = two cadavers, 24 samples; $p < 0.05$). However, when broken down by flap type, only the skin and composite flaps demonstrated significant differences between the old and young groups. For 3-0 suture tearing forces, the young group demonstrated signifi-

cant differences between composite, skin, and SMAS flap type in decreasing order ($p < 0.05$ for all comparisons). In the old group, although the skin flap and SMAS flap demonstrated significantly less 3-0 suture tearing force as compared with the composite flap, no difference was noted between the skin flap and the SMAS flap ($p < 0.05$) (Fig. 4, *below*).

Overall, tissue stress-relaxation was similar between the old group (n = three cadavers, 54 samples) and the young group (n = two cadavers, 36 samples). However, within both age groups, the skin flap demonstrated significantly greater stress-relaxation as compared with the SMAS and composite flaps ($p < 0.05$ for all comparisons). No difference was noted between SMAS and composite flaps in either age group.
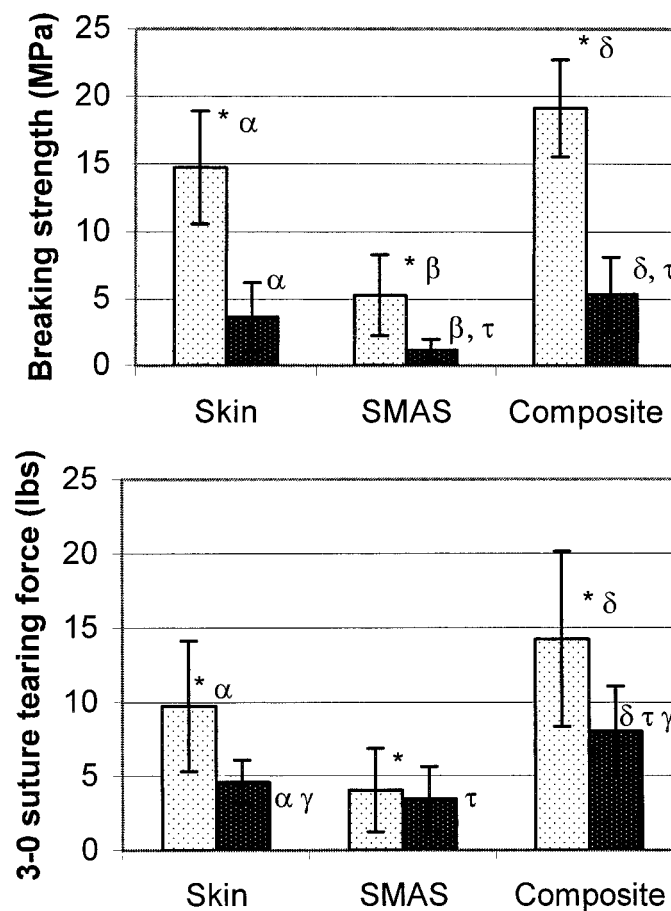

FIG. 4. (*Above*) Analysis of tissue breaking strength (*Mpa*) by flap type and age. Note the significant differences between the young (*open bars*, n = 24) and old (*solid bars*, n = 36) groups and between the different flap types (n = 20 for each flap type). *T-bars* indicate SDs. *, α, β, δ, π = $p < 0.05$. (*Below*) Analysis of 3-0 suture tearing force in pounds by flap type and age. Note the significant differences between the young (*open bars*, n = 24) and old (*solid bars*, n = 36) groups and between the different flap types (n = 20 for each flap type). *T-Bars* indicate SDs. *, α, β, δ, π = $p < 0.05$.

Tissue creep was similar between the old group ($n =$ two cadavers, six samples) and the young group ($n =$ two cadavers, six samples). The number of samples tested for tissue creep was too small to compare the three flap types within each age group.

DISCUSSION

In the skilled surgeon's hand, a variety of rhytidectomy techniques can achieve excellent results, and the technique must be tailored to the individual patient's features and aging changes. Among the significant limitations of the procedure is the tendency of the result achieved on the operating table to relax over time (creep and stress-relaxation), the limitations of blood supply, and strength of the tissue in exerting tension on the flaps. The tension exerted laterally by suturing, whether in the facial or cervical region, is attenuated medially by the viscoelastic properties of the facial flaps, limiting the sustained changes on the nasolabial folds, corner of the mouth, jowls, platysmal bands, and cervicomental angle. In addition, the overpulled appearance, manifested partly by unnatural tension lines along the vector of posterosuperior pull of the flaps, should be avoided. Knowledge of the biomechanical properties of the aging facial skin and underlying SMAS can aid in the choice of surgical technique.

In this study, we tested fresh cadaveric tissue from eight cadavers within 72 hours of the time of death. Preliminary tensiometry and relaxation tests of discarded tissues from a rhytidectomy specimen demonstrated that when kept cooled, the biomechanical properties of these tissues did not change significantly over the 72-hour period. The biomechanical and viscoelastic differences between skin, SMAS, and composite flaps taken from the fresh cadavers' facial and cervical regions were measured and compared.

As expected, skin will tolerate higher degrees of tension in suturing than the underlying SMAS, particularly in the facial region. As the patient ages, the SMAS becomes more attenuated, which further limits the tension that can be exerted on the facial SMAS flap when raised separately. This is demonstrated in this study by the significantly lower tissue breaking strength and 3-0 suture tearing strength noted in the old group (>65 years) as compared with the young group (≤65 years old) and that the composite flaps in both the young and old

groups had significantly greater tissue breaking strength and 3-0 suture tearing force as compared with the SMAS flap alone (Fig. 4). Extensive undermining of the skin flap superficial to the SMAS layer, as is done in most rhytidectomy techniques, compromises the blood supply and hence limits the degree of tension that can be placed on the skin flap.[10,11] Thus, greater tension can be placed on the composite flap than when the two flaps are raised separately, potentially allowing greater changes in the face medial to the cutaneous retaining ligaments along the zygoma and masseter muscle.[5,14] In the composite flap technique, the tension of the sutures is placed on the relatively stiff SMAS, with a more even transmission of the posterosuperior pull on the facial flap minimizing the tendency for the overpulled look with unnatural visible tension lines. In addition, the deep tacking sutures support the majority of the tension, protecting the more superficial dermal plexus and avoiding subsequent skin necrosis.[21]

As have other investigators, we confirmed that the SMAS layer exhibits significantly less stress-relaxation and creep when compared with the subcutaneous skin flap.[18–20] This property of the SMAS has led the majority of aesthetic surgeons to plicate, excise, or elevate the SMAS to tighten it, with reported benefits on the long-term results.[18,20,22,23]

On the basis of the data reported in this study, it seems that the composite layer, although comprising both skin and SMAS, acquires the viscoelastic properties of the SMAS layer. Fine connections exist between the dermis and the SMAS layer. We propose that the maintenance of these connections allows the composite layer to adopt the decreased stress-relaxation and creep of the SMAS layer and plays a role in maintaining long-term results.

A limitation of this study is the short time period over which the viscoelastic properties of stress relaxation and creep were measured. Long-term studies could only be done on live patients, which is not feasible, and the cadaver skin deteriorates over time. It is reasonable to speculate that viscoelastic properties in the short run would be somewhat predictive of tissue relaxation over clinical time frames because of the intrinsic differences in collagen and elastin organization accounting for the acute changes.

It is noteworthy that the cervical flaps, despite their strength, exhibit greater stress-

relaxation and creep than the facial flaps. This correlates to a clinical observation that the aging neck tends to relapse faster than the structures above the mandibular border after rhytidectomy, requiring an isolated cervical rhytidectomy as a secondary procedure at a time when the rejuvenation at the mandibular border has been maintained.

In patients who do not require different vectors of pull for the SMAS and overlying skin, the composite technique offers some biomechanical advantages. When different vectors are beneficial, a limited posterior dissection in the subcutaneous plane in the region just inferior to the zygomatic arch can be performed, retaining most of the flap as a composite structure and undermining the composite flap medial to the retaining ligaments over the zygomaticus major muscle. Limited superficial undermining with excellent outcomes has been previously described.[24]

In conclusion, these biomechanical studies on facial flaps indicate[1] that the skin and composite flaps are substantially stronger than the SMAS flap, allowing greater movement laterally of the SMAS and overlying subcutaneous fat in a composite flap subjected to clinically exerted tensions. Second, the SMAS and composite flaps are less viscoelastic than the isolated skin flap, suggesting more potential skin relaxation over time with the latter. Third, the cervical flaps are more viscoelastic than facial flaps, suggesting earlier relaxation of the neck than the face.

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