Biomechanical Properties of Materials Used in Static Facial Suspension

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Objective: To compare the biomechanical properties of the superficial (human acellular dermis); (AlloDerm; LifeCell Corp, Branchburg, NJ) and deep layers of cadaveric dermis and expanded polytetrafluoroethylene (ePTFE); (Gore-Tex; W. L. Gore & Associates, Flagstaff, Ariz).

Methods: Sixteen samples of superficial dermis (AlloDerm), 12 samples of deep dermis, and 12 samples of ePTFE were axial loaded on a materials testing machine. Maximum load to failure and stiffness were calculated and statistical analysis was performed to compare the materials.

Results: Dermis samples had statistically greater mean stiffness compared with ePTFE samples. There was no statistical difference of maximum load to failure comparing ePTFE with superficial dermis. There was a statistical difference in maximum load to failure between ePTFE and deep dermis. There was no statistical difference between the superficial and deep layers of the dermis with respect to stiffness or maximum load to failure.

Conclusions: Cadaveric dermis has some biomechanical properties to be a superior material for static facial suspension. There was larger than expected variability in both parameters (stiffness and maximum load to failure) tested in dermis samples, which may correlate with occasional clinical failure.

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Facial paralysis resulting from head and neck malignancy resection is a devastating problem for both the patient and the reconstructive surgeon. A number of options are available for facial reanimation including cable nerve grafting, muscle transpositions, and static facial sling procedures. Static facial suspension is frequently used when the patient's temporalis muscle has been sacrificed in the extirpative procedure or when the patient declines muscle transposition. It is also used in conjunction with cable nerve grafting to provide improved facial symmetry and oral competence while awaiting functional recovery of the grafted facial nerve. Two popular materials currently used for static facial suspension are expanded polytetrafluoroethylene (ePTFE); (Gore-Tex; W. L. Gore & Associates, Flagstaff, Ariz) and human acellular dermis (AlloDerm; LifeCell Corp, Branchburg, NJ). Both of these materials have the advantage over autologous fascia lata of requiring no patient donor site. While ePTFE is easy to use and readily available, we have found in our population of patients treated with irradiation a tendency for infection or extrusion that necessitated removal of the sling.1 Extrusion and/or infection of ePTFE slings has been reported by other authors.2-4 This led to our use of acellular dermis in this patient population. In our series of more than 50 patients, none experienced infection or extrusion of human acellular dermis despite radiation therapy.1 We have, however, observed variability in the longevity of human acellular dermis static facial suspension in this patient population.

Critics of the use of human acellular dermis in static facial suspension cite postoperative stretching, which is often unpredictable, and results in facial ptosis and loss of oral competence. Although we have noted some stretching of the sling postoperatively, most patients have had good outcomes.1 Fischer and Frodel5 likewise reported good to excellent results in 9 of 10 patients who underwent static facial suspension using human acellular dermis. Postoperative stretching is not limited only to acellular dermis but is also seen with ePTFE reconstructions. Constantinides et al6 reported sling laxity requiring revision in 5 of 6 patients undergoing ePTFE sling reconstruction.
There are few studies looking at the biomechanical properties of human acellular dermis or ePTFE. Our current objective was to further characterize the biomechanical properties of commercially available acellular dermis and ePTFE. Additionally, we sought to determine if processed, deep dermis may have improved strength characteristics compared with commercially available AlloDerm (superficial dermis) and therefore examined the stiffness and load to failure values of this material as well.

**METHODS**

Lifecell Corporation obtains cadaveric dermis from tissue banks. The dermis is then processed to remove cellular and infectious components. The specimens are then freeze-dried and packaged. Human acellular dermis samples were rehydrated according to the package insert from LifeCell Corporation. Each 3 × 7-cm sample was then cut into four 3.5 × 1.5-cm pieces. Sixteen samples of superficial dermis (AlloDerm), 12 samples of deep dermis (also harvested by LifeCell Corporation) were obtained. Human acellular dermis thicknesses, both superficial and deep, were approximately 0.8 to 1.0 mm per package measurements. Twelve samples of 1-mm-thick ePTFE were also prepared to the same dimensions. Each sample was then placed into the serrated grips of an MTS Minibionix testing machine (MTS Systems Corp, Eden Prairie, Minn). The gauge length between grips was 22 mm. Axial loading was then initiated at a rate of 10 mm/min until sample failure. The failure site of the dermis samples was always between the grips suggesting that the grips themselves did not alter the findings. The ePTFE samples did fail closer to, but never within, the grips. A load (newtons) to extension (millimeters) graph was then plotted using Testworks 4.05 software (MTS Systems Corp) and maximum load to failure and stiffness values calculated. Stiffness is defined as the slope of this curve. This process was repeated for all samples of superficial and deep dermis and ePTFE. After the data were tabulated, F tests were performed and subsequent Kruskal-Wallis nonparametric tests were used to compare the 3 groups. Mann-Whitney U tests were performed to reveal statistical differences between each test group.

**RESULTS**

The mean and SEM of each group are shown in the Table. The mean stiffness of superficial dermis was 29.1 N/mm and ranged between 12.5 and 45.6 N/mm. The deep dermis mean stiffness was 30.4 N/mm and ranged between 17.1 and 53.0 N/mm. The ePTFE mean stiffness was 10.7 N/mm and ranged between 9.7 and 11.8 N/mm. The ePTFE samples were less stiff than the dermis samples, which supports our subjective observation of noticeable stretching before their breaking. An F test revealed unequal variances between ePTFE and superficial dermis ($P < .001$) and deep dermis ($P < .001$). Variances were similar between superficial dermis and deep dermis ($P = .35$). This variance is notable in the Figure. To avoid violating assumptions of equal variance, nonparametric tests were also subsequently used for the load to failure data. The mean load to failure among all 3 groups was statistically different (Kruskal-Wallis, $P = .01$). Mann-Whitney U tests showed no difference between the superficial and deep layers ($P = .25$) or between the superficial layers and ePTFE ($P = .10$). The ePTFE samples were significantly different from the deep dermis samples ($P = .001$).

<table>
<thead>
<tr>
<th>Test Material</th>
<th>Load to Failure, N</th>
<th>Stiffness, N/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial dermis</td>
<td>142.4 (16.2)</td>
<td>29.1 (2.7)</td>
</tr>
<tr>
<td>Deep dermis</td>
<td>194.2 (24.5)</td>
<td>30.4 (3.6)</td>
</tr>
<tr>
<td>ePTFE</td>
<td>108.6 (14.6)</td>
<td>10.7 (18)</td>
</tr>
</tbody>
</table>

*Data are given as mean (SEM).
†Superficial dermis is marketed by LifeCell Corp as AlloDerm; ePTFE (expanded polytetrafluoroethylene) is marketed by W. L. Gore & Associates as Gore-Tex.

Load to failure results are also shown in the Table. The mean maximum load to failure for superficial dermis was 142.4 N, with a range of 42.6 to 254.6 N. The mean maximum load to failure for deep dermis was 194.2 N, with a range of 103.1 to 328.8 N. The mean maximum load to failure for ePTFE was 108.6 N, with a range of 103.2 to 114.9 N. Like the stiffness data, an F test revealed unequal variances between ePTFE and superficial dermis ($P < .001$) and deep dermis ($P < .001$). Variances were similar between superficial dermis and deep dermis samples ($P = .35$). This variance is notable in the Figure. To avoid violating assumptions of equal variance, nonparametric tests were also subsequently used for the load to failure data. The mean load to failure among all 3 groups was statistically different (Kruskal-Wallis, $P = .01$). Mann-Whitney U tests showed no difference between the superficial and deep layers ($P = .25$) or between the superficial layers and ePTFE ($P = .10$). The ePTFE samples were significantly different from the deep dermis samples ($P = .001$).

**COMMENT**

In this study we examined the load to failure and stiffness of the superficial and deep layers of processed cadaveric dermis and ePTFE. We hypothesized that dermis samples would have a higher mean load to failure compared with ePTFE samples. This difference was statistically significant when comparing deep dermis with ePTFE, but not when comparing superficial (AlloDerm) samples with ePTFE samples. We also hypothesized that ePTFE samples would be less stiff than the dermis samples, which was statistically supported by our data. Of note was the large variability of load to fail-
ure measurements in the dermis groups compared with the ePTFE group. While most of our patients undergoing static facial slings with superficial dermis (AlloDerm) have had good outcomes, this variability may explain why we have seen several sling failures.

In 1999, Lemer et al. measured the stiffness and load to failure of superficial dermis (AlloDerm) using 1 × 1-cm specimens. They compared AlloDerm with autologous rectus fascia, solvent-dehydrated fascia lata, and freeze-dried fascia lata. They found the mean maximum load to failure and stiffness of AlloDerm to be 319 N and 118.3 N/mm, respectively. Our stiffness and maximum load to failure results were notably lower than these values and our sample variability was higher. This can be explained by our use of longer samples. Our samples were 1.5 × 3.5-cm long, resulting in a greater gauge length between the grips of the material testing machine, thus, making the specimens less stiff and likely more variable in both stiffness and failure strength.

In 2001, Choe et al. recorded the maximum load to failure and displacement of 2 × 5-cm specimens of AlloDerm, ePTFE, fascia lata, polypropylene (Prolene) mesh, rectus fascia, and vaginal wall mucosa using a tensiometer (Instron Co, Canton, Mass). The mean ± SD maximum load to failure for the AlloDerm group was 144±44 N, with a displacement of 3.1 ± 1.9 mm. The PTFE group averaged 136 ± 17 N, with a displacement of 57.0 ± 12.5 mm. These findings more closely correlate with our data.

In 2002, Sclafani et al. determined maximum load, maximum stress, and elastic modulus of 1 × 4-cm samples of AlloDerm, DuraDerm (Collagenesis, Inc, Beverly, Mass), cadaveric fascia, and Tutoplast (Tutogen Medical, Inc, Alachu, Fla) fascia. Their results showed Tuto- plast (fascia lata) and AlloDerm to have superior maximum load to failure compared with cadaveric fascia lata and DuraDerm. The mean load to failure of their AlloDerm samples was considerably less than our results (approximately 50 N vs 142.4 N).

There are limitations when studying the biomechanical properties of human tissue in an in vitro setting. Individual patient variables such as radiation exposure, nutritional status, multivector masticatory forces, and incorporation of the sling into surrounding tissue are difficult to reproduce. The ideal study would also test the stretching of cadaveric dermis samples over several months to help surgeons predict the need for sling over-correction. Despite these limitations, our data suggest that human acellular dermis exhibits biomechanical characteristics that potentially make it a superior facial suspension material compared with ePTFE. Stiffness for both dermal layers was greater than that for ePTFE. Mean maximum load to failure was greater for both dermis samples (not statistically significant with superficial vs ePTFE). However, considerable variability in the dermis samples was noted, which may correlate with clinically observed sling laxity in selected patients. Interestingly, we noted several dermis samples had translucent areas that seemed to correlate with decreased load to failure. These areas were noted in 2 of the 4 samples obtained from the same 3 × 7-cm specimen and appeared to be thinner areas relative to harvesting of the cadaveric dermis. Some degree of variability in dermal specimens is not unexpected since the tissues are harvested manually with a dermatome at the tissue bank before processing at LifeCell Corporation. This observation suggests that a single weak link in an otherwise strong specimen could contribute to clinical sling failure. Perhaps harvesting thicker sections of dermis may decrease specimen strength variability and improve clinical outcomes after static facial suspension. It would be interesting to assess the biomechanical properties of full-thickness, processed dermis samples.

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REFERENCES


