Progressive Scalp Thinning Over Mesh Cranioplasty and the Role of Lipotransfer

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**Objectives:** To evaluate the role of lipotransfer in progressive scalp thinning following titanium mesh cranioplasty.

**Methods:** Retrospective review of single surgeon, single tertiary referral experience of all patients who underwent mesh cranioplasty. Patient demographics, prior radiotherapy, frequency and timing of scalp thinning, and treatment course data were obtained.

**Results:** A total of 144 patients were included, 77 male and 67 female with mean ages 58.2 and 54.8, respectively. One hundred four patients (72%) developed mesh exposure or impending exposure requiring reconstruction. Fifty-six patients (54%) with scalp thinning were treated with lipotransfer, 40 of which were salvaged and the remainder of these patients definitively managed with cranioplasty and reconstruction. Prior radiotherapy was found to be associated with higher rates of mesh exposure or impending exposure requiring reconstruction. There was no predictive value of response to lipotransfer.

**Conclusion:** Lipotransfer is a useful technique in managing moderate scalp thinning following mesh cranioplasty. Mesh exposure or severe thinning require definitive cranioplasty and reconstruction.

**Key Words:** Titanium, mesh, cranioplasty, lipotransfer, thinning.

**Level of Evidence:** IV

**INTRODUCTION**

The skull establishes an anatomic boundary between intracranial and extracranial contents and provides robust protection to central nervous system components. Cranial defects can be the result of congenital deformities, traumatic injuries, infection, and surgical or oncological ablative procedures. Cranialplasty is the repair of cranial defects of any size, from holes to larger defects, and there is evidence of cranioptlasty dating back several millennia. Incans used gold to fill in trephination sites around 3000 BC, and the first successful xenoplastic bone graft cranioplasty was reported in 1668. Cranioptlasty has evolved significantly over the past several centuries, and today the ideal reconstruction would 1) reestablish normal neurocranial anatomical boundaries, 2) provide durable, long-lasting reconstruction, and 3) optimally reconstitute or support overlying soft tissues to give the best possible aesthetic outcome.

Cranioptlasty success relies in part on defect size, location, and patient comorbidities, but it also relies on the reconstructive method. The optimal material for cranioplasty is the one that is inexpensive and readily available, biocompatible, non-thermoconductive, radiolucent, and light and malleable yet strong enough to withstand pressure overtime. Unfortunately, no single material perfectly fits these criteria to be a surgically and aesthetically desirable implant. The gold-standard material for cranioplasty has been autologous bone, however, this adds donor site morbidity and is susceptible to bone resorption over time. Furthermore, recreation of the natural contour of the skull can be difficult with autologous sources, and there may be insufficient volume of autologous bone for reconstruction of larger defects. Multiple alloplastic materials have been developed and refined for skull reconstruction such as hydroxyapatite, polymethyl methacrylate (PMMA), polyetheretherketone (PEEK), and titanium mesh.

Titanium mesh is cheap, easy to manipulate, capable of spanning large defects, and effective for short-term cranial reconstruction, and it has frequently been used by reconstructive surgeons over the past several decades. While simple and immediately effective, skin-over-titanium mesh may not provide a durable reconstruction. Herein, we review our experience over the past two decades with titanium mesh cranioplasty to better characterize its long-term durability.
METHODS
We performed a retrospective review of patients who underwent titanium mesh cranioplasty of a single area of calvarium between 1997 and 2013. Institutional review board approval was obtained from JPS (John Peter Smith Hospital, Fort Worth, TX). Data was collected by the senior author (Y.D.) and analyzed in aggregate. This study represents a single center, single surgeon, tertiary care referral practice experience. We excluded patients who did not have follow-up 4 years after reconstruction. All patients included in the series who underwent reconstruction of the temporal skull lacked a temporalis muscle; the muscle had either been excised or used as a flap for skull base reconstruction. Patients with an intact temporalis muscle over the mesh cranioplasty were excluded.

Scalp thinning is defined as atrophy of intact, normal scalp skin overlying the entire cranioplasty mesh and not isolated to abnormal scalp tissue such as prior incision sites. A spectrum of scalp thinning is encountered clinically. No thinning can be observed. Impending exposure is defined as clinically notable skin thinning with intact dermis thick enough to tolerate lipotransfer with an injection cannula without tearing of the dermis. Mesh exposure is defined by frank exposure of cranioplasty mesh or severe thinning to the point where the dermis would tear from lipotransfer cannula injection attempt.

We performed statistical analysis in SPSS version 24 (IBM Corporation, Armonk, NY) and GraphPad Prism version 7 (Graphpad Software, La Jolla, CA). We compared gender, a history of external beam radiotherapy (EBRT), and location of reconstruction to the development of scalp thinning and impending mesh exposure individually with chi-square tests and logistic regression.

RESULTS
One hundred forty-four patients met inclusion criteria for our study. Seventy-seven patients were male with an average age of 58.2 years (range 18–81) and 67 females met inclusion criteria with an average age of 54.8 years (range 18–77). Rates of thinning requiring surgical revision in male and female patients by location, average cranial defect size, average time to thinning from initial reconstruction, and whether or not the patient underwent EBRT are represented in Table I. Seventy-five patients underwent frontal bone reconstruction. Of these, 49 patients underwent EBRT as part of their treatment. Thirty-eight of 49 (77.5%) patients developed thinning skin with mesh exposure or impending exposure an average of 4.2 and 3.8 years after initial reconstruction and required revision surgery in males and females, respectively. Of the 26 patients who did not undergo EBRT, 16 developed thinning an average of 6.7 and 5.8 years after initial reconstruction requiring surgical intervention in males and females, respectively.

Of the 52 patients who underwent reconstruction of the temporal skull, 42 underwent EBRT. Thirty-eight of 42 (90%) patients developed thinning an average of 3.2 and 2.8 years after reconstruction with mesh exposure or impending exposure requiring surgical revision. Twelve patients did not have EBRT, and of these, seven developed thinning an average of 4.6 and 4.1 years after reconstruction with plate exposure or impending exposure requiring surgical revision.

Seven patients underwent occipital reconstruction, and three underwent EBRT. One (33%) developed thinning 8 years postoperatively requiring revision. In the four patients who did not have EBRT, one (25%) developed thinning with exposure 9.5 years after initial reconstruction. Ten patients underwent parietal reconstruction, and seven underwent EBRT. Three of the seven patients developed thinning averaging 2.8 and 9 years after reconstruction requiring revision surgery. No thinning was observed in the patients who did not undergo EBRT.

Figure 1 demonstrates the number of patients who developed exposure of mesh (part A) and those who underwent EBRT (part B) compared to those who did not, divided by operative location. Figure 2 depicts the differences in exposure by reconstructive site and EBRT exposure. Patients who underwent EBRT were significantly more likely to develop severe skin thinning requiring revision or frank plate exposure ($P = .0028$). Subgroup analysis demonstrates statistically significantly more mesh exposures in the temporal region in patients who have undergone EBRT compared to those who did not have history of EBRT ($P = .0084$). Also, patients with frontal or temporal mesh were significantly more likely to develop severe thinning with mesh exposure than patients with parietal or occipital mesh ($P = .0002$). There was no statistical difference in the rate of exposure between males and females. Logistic regression analysis found that the site of reconstruction and EBRT were significant predictors of mesh exposure ($P = .005$ and $P = .002$, respectively), but gender was not ($P = .757$).

In total, of 144 patients meeting study criteria, 104 (72%) developed exposure or impending exposure requiring surgical reconstruction. 56 (54%) patients with impending exposure were treated with lipotransfer; while

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### TABLE I.

<table>
<thead>
<tr>
<th>Radiation exposure</th>
<th>Rates of thinning and impending mesh exposure</th>
<th>Average no. years to exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males ($n = 77$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (range): 58.2 (18–81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>EBRT</td>
<td>No EBRT</td>
</tr>
<tr>
<td>Frontal</td>
<td>21/27</td>
<td>7/14</td>
</tr>
<tr>
<td>Temporal</td>
<td>22/24</td>
<td>5/7</td>
</tr>
<tr>
<td>Parietal</td>
<td>1/3</td>
<td>0/1</td>
</tr>
<tr>
<td>Occipital</td>
<td>1/2</td>
<td>0/1</td>
</tr>
<tr>
<td>Females ($n = 67$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (range): 54.8 (18–77)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>EBRT</td>
<td>No EBRT</td>
</tr>
<tr>
<td>Frontal</td>
<td>17/22</td>
<td>9/12</td>
</tr>
<tr>
<td>Temporal</td>
<td>16/18</td>
<td>2/5</td>
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<tr>
<td>Parietal</td>
<td>2/4</td>
<td>0/2</td>
</tr>
<tr>
<td>Occipital</td>
<td>0/1</td>
<td>1/3</td>
</tr>
</tbody>
</table>

There was no significant difference in gender distribution among the different reconstructive sites. EBRT = external beam radiotherapy; N/A = not applicable.
40 (71%) patients were salvaged from further surgery and 16 (29%) of these patients required lipotransfer more than two times within 1 year, and, thus, were definitively managed with a cranioplasty and either a local scalp flap or autologous free tissue transfer. Fourteen (87%) of the 16 patients failing lipotransfer had undergone EBRT compared to 30 (75%) of the 40 patients who were salvaged by lipotransfer. EBRT was not found to be associated with mesh exposure.

Fig. 1. Number of patients who developed mesh exposure A) by location of the reconstruction, and the number of patients who underwent EBRT, B) by location of the reconstruction. Patient’s with mesh over the frontal and temporal bones were significantly more likely to experience exposure ($P = .0002$). EBRT = external beam radiotherapy.

Fig. 2. Development of mesh exposure by site of reconstruction and exposure to EBRT. Part A depicts patients who did not develop exposed mesh, while part B depicts those that did. Patients who developed mesh exposure were significantly more likely to have undergone EBRT ($P = .0028$). EBRT = external beam radiotherapy.
decreased rate of salvage using lipotransfer in impending exposure \( (P = .47) \). Forty-eight (46%) patients with mesh exposure or impending exposure with skin too thin tolerate lipotransfer underwent mesh removal, cranioplasty with autologous bone, or a preformed implant, and coverage with non-radiated skin from either a local scalp flap or autologous free tissue transfer. Among these patients, four developed subsequent partial exposure at 6, 7, 11, and 18 months postoperatively, respectively, and were treated with local flaps and cranioplasty exchange. Of note, all four of these patients had undergone EBRT.

**DISCUSSION**

We report an overall high rate (72%) of long-term severe skin thinning and mesh exposure requiring surgical reconstruction. Patients with titanium mesh in any calvarial defect are at risk of impending scalp thinning over the mesh and at risk of exposure. Based on our results, patients who underwent EBRT as part of their management were at significantly greater risk of exposure, particularly in the temporal region when compared to the frontal, parietal, and occipital areas. Our data are limited by the number of patients in the parietal and occipital defect groups and thus is inadequately powered for regional comparison. One additional limitation of this study is the lack of a control group. The true incidence of scalp thinning and ultimate mesh exposure in both the radiated and non-irradiated patient is unclear. Our data suggest that parietal and occipital defects develop scalp thinning much later than frontal and temporal defects; thus, extended follow-up of up to 15 years is necessary.

The mechanism by which the scalp thins due to the underlying titanium mesh is also unclear, and histologic studies may be useful to study the interface between the soft tissue and titanium mesh. Of note, the senior author has only observed thinning in the temporal region when the temporalis is absent.

To date, no studies have reported on outcomes of prophylactic autologous fat injection and mesh exposure.
Studies have demonstrated varying degrees of temporal hollowing following coronal approaches for trauma and other procedures, and autologous fat grafting is used often for cosmetic purposes, popularized by Coleman in the 1990s.\textsuperscript{15} Choi et al., for example, reported on autogenous fat grafting for temporal hollowing after decompressive craniectomy and found it improved patient reported outcomes at 1 month and 1 year.\textsuperscript{16} The senior author (Y.D.) has previously demonstrated lipotransfer as an effective adjunctive technique for patients following head and neck reconstruction.\textsuperscript{17} McNichols et al. also report on dermal fat grafting outcomes in five patients in 2011.\textsuperscript{18} Huang et al.’s anatomic study demonstrated four fat compartments in the temporal region ideal for fat grafting.\textsuperscript{19} This was followed up by a study looking at 142 autologous fat grafts with both subjective improvement as well as clinical improvement of two grades on average based on the Hollowness Severity Rating Scale.\textsuperscript{20}

Fig. 4. A) patient undergoes mesh cranioplasty with local tissue rearrangement. B) One month postoperative with slight dehiscence and impending mesh exposure. C) Undergoes patient-specific implant with local tissue rearrangement. D) Thinning of skin flap noted with impending mesh exposure at 5 months post–patient-specific implant. E) Implant exposure at 8 months postop. F) Implant removed, non-viable soft tissue debrided. G) titanium mesh with anterolateral thigh free flap reconstruction. H) Immediate post-op. I) Two months post–implant removal with titanium mesh replacement and free flap reconstruction. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]
Our data support the conclusion that local transfer of vascularized tissue and lipotransfer are successful in managing thinned tissue and small areas of mesh exposure after revision cranioplasty via replacement of the titanium mesh with autologous bone or a patient specific non-titanium implant. In our study, of the patients with scalp thinning and impending mesh exposure, appropriate for free tissue transfer, 29% ultimately required local or free flap reconstruction with replacement of the titanium mesh. The senior author (Y.D.) has not encountered any further thinning or exposures following replacement with non-titanium implants or autologous bone.

There are many benefits of titanium mesh cranioplasty including cost effectiveness, ease of manipulation, biocompatibility and low infection rate, capability of spanning large defects, and efficacy as a short-term cranial reconstruction are recognized and outweigh the risks of its propensity to extrude over time. In oncologic surgery, the initial calvarial defect is often unpredictable, and mesh cranioplasty is an excellent option due to its malleable properties. Given its propensity for skin thinning and exposure, particularly in patients who have undergone radiation therapy, mesh cranioplasty combined with lipotransfer may be an ideal reconstructive option in these patients, as it can delay or eliminate the need for larger reconstructive procedures involving implant replacement and free tissue transfer. Irradiated patients appear to be at higher risk for failing prophylactic lipotransfer and for wound breakdown after definitive reconstruction. We present our algorithm for addressing scalp thinning and mesh exposure in Figure 3. Figure 4 is a patient example of impending mesh and implant exposure ultimately requiring free tissue transfer.

CONCLUSION

Overall, simple cranioplasty with titanium mesh alone for calvarial defects, while initially safe, efficient, and cosmetically acceptable, has been found to result in progressive overlying skin thinning with high rates of exposure over time. Prophylactic lipotransfer to thinned areas allows for simple and effective treatment of the thinned areas to salvage impending mesh exposure, which can be addressed definitively with extensive procedures involving mesh removal with custom implant replacement and local or free tissue transfer.

BIBLIOGRAPHY