Full-Thickness Skin Grafting for Local Defect Coverage Following Scalp Adjacent Tissue Transfer in the Setting of Cranioplasty

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Introduction: Numerous techniques have been described to overcome scalp deficiency and high-tension closure at time of cranioplasty. However, there is an existing controversy, over when and if a free flap is needed during complex skull reconstruction (ie, cranioplasty). As such the authors present here our experience using full-thickness skin grafts (FTSGs) to cover local defects following scalp adjacent tissue transfer in the setting of cranioplasty.

Methods: By way of an institutional review board-approved database, the authors identified patients treated over a 3-year period spanning January 2015 to December 2017, who underwent scalp reconstruction using the technique presented here. Patient demographics, clinical characteristics, technical details, outcomes, and long-term follow up were statistically analyzed for the purpose of this study.

Results: Thirty-three patients, who underwent combined cranioplasty and scalp reconstruction using an FTSG for local donor site coverage, were identified. Twenty-five (75%) patients were considered to have ''high complexity'' scalp defects prior to reconstruction. Of them, 12 patients (36%) were large-sized and 20 (60%) medium-sized; 21 (64%) grafts were inset over vascularized muscle or pericranium while the remaining grafts were placed over bare calvarial bone. In total, the authors found 94% (31/33) success for all FTSGs in this cohort. Two of the skin grafts failed due to unsuccessful take. Owing to the high rate of success in this series, none of the patient's risk factors were found to correlate with graft failure. In addition, the success rate did not differ whether the graft was placed over bone verses over vascularized muscle/pericranium.

Conclusion: In contrary to previous studies that have reported inconsistent success with full-thickness skin grafting in this setting, the authors present a simple technique with consistent results—as compared to other more complex reconstructive methods—even in the setting of highly complex scalp reconstruction and simultaneous cranioplasty.

Key Words: Calvarium, cranioplasty, full-thickness graft, scalp, scalp reconstruction, skin graft, skull reconstruction

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Providing a reliable scalp closure, with little-to-no tension, is an absolute prerequisite for achieving successful cranioplasty with customized cranial implants. Unfortunately, surgeons are challenged regularly with unexpected scalp dehiscence following cranioplasty and then secondary hardware infections related to wound disruption. As such, many now move straight to the more complex option—free tissue transfer—which accompanies high morbidity and increased resources. In parallel, scalp closure using adjacent tissue transfer has also proven time-tested results with improved esthetic outcomes, including tertiary referrals involving traumatized and vascular-compromised scalps. However, for some, local tissue rearrangement may be insufficient for scalp closure during concomitant cranioplasty.[1,2] In addition, oncological patients who have undergone irradiation and re-operation with significant scalp atrophy are even more challenging with respect to achieving a long-term durable scalp closure.[3–7]

Numerous techniques have been described to correct scalp deficiency at time of cranioplasty, including biological materials, healing by secondary intention, staged tissue expansion, split-thickness skin grafts (STSGs), and free tissue transfer.[8–10] Regardless, the ideal method of coverage should provide durable scalp closure with little-to-no tension and an esthetically pleasing result.[8,9] In addition, the ideal technique uses the least amount of operative time and harbors the lowest amount of accompanying morbidity.[9]

In our database spanning 450 skull reconstruction patients, we have found that full-thickness skin grafts (FTSGs)—applied to bare calvarium, muscle, or pericranium—is both safe and reliable in achieving these goals with minimal risk for complication. Following our previously described scalp and dura augmentation techniques (using rectus fascia), we herein describe another method to overcome co-existing scalp deficiencies using FTSGs for local donor defects following complex adjacent tissue transfer and present within our preliminary experience in various instances before, during, or after cranioplasty.[11,12]

MATERIALS AND METHODS

This retrospective database review was approved by the Johns Hopkins University School of Medicine Institutional Review Board and encompasses the Neuroplastic Surgery Center Database. All patients treated over a 3-year period, spanning January 2015 to December 2017, were reviewed. Selection criteria included those who underwent FTSG coverage of local donor sites following scalp adjunct tissue transfer and concomitant cranioplasty. Patient demographics, clinical characteristics, technical details, and outcomes were statistically analyzed using Excel software (Microsoft, Redmond, WA).

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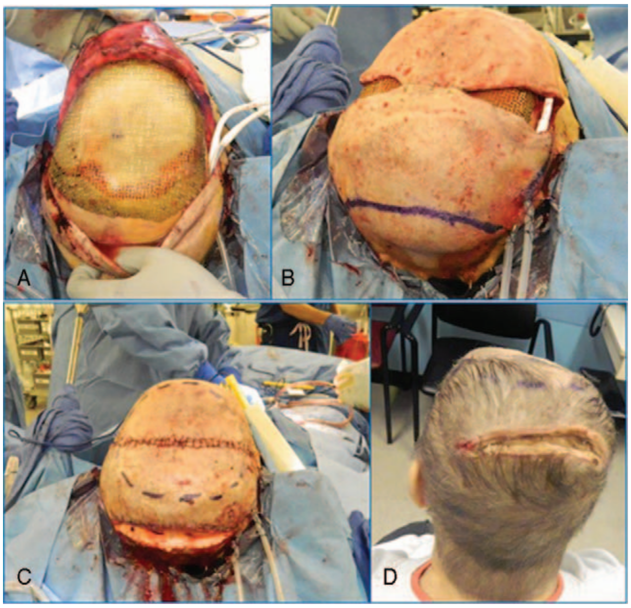

FIGURE 1. (A–D) A 68-year-old female presented with recurrence of grade 3 meningioma. Original resection performed 7 years prior, followed by radiation therapy. At time of re-resection, she presented with a contracted scalp with atrophy. (A) A large bilateral cranioplasty with titanium mesh implant. (B) Complex scalp closure over the titanium mesh in both parietal regions and an occipital bilateral, advancement flap to advance the scalp forward for tension-free closure. (C) Closure of the primary scalp defect accompanied by adjacent tissue transfer and FTSG of the local donor site. (D) Patient at 3 months with FTSG contraction/shrinkage in the concealed occipital area, in an area well-hidden by hair. FTSG, full thickness skin graft.

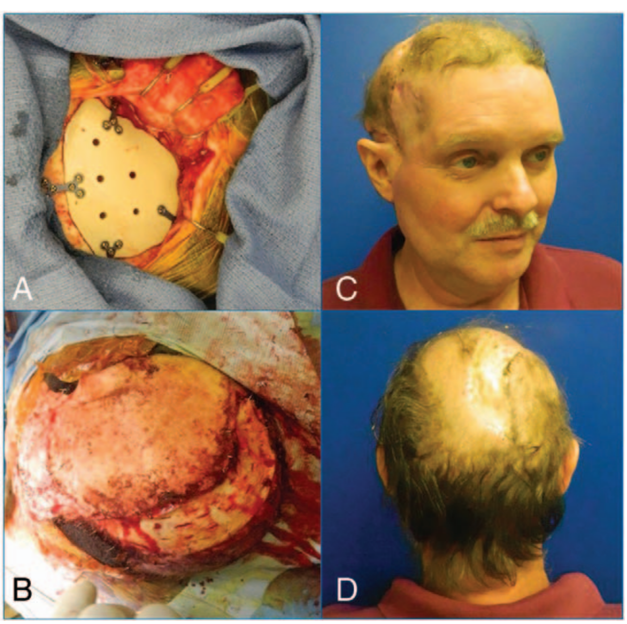

FIGURE 2. (A–D) A 58-year-old male presented to neurosurgery with a recurrent glioblastoma multiforme. Of note, he had both many previous surgeries and irradiation to his head. At initial presentation, he had a large-sized, right-sided skull defect in the area of previous craniotomy. (A) A customized cranial implant made of poly-ether-ether-ketone was used for single-stage cranioplasty reconstruction following resection of the recurrent brain tumor. (B) A large, right-sided fasciocutaneous scalp flap, based on the superficial temporal system, transposed anteriorly over the cranial implant. In turn, the local donor site was covered with a large-sized full thickness skin graft. Figures C and D demonstrate the patient's appearance at 1-year follow-up.

Surgical Technique

The technique involves initial component separation with transposition of a partial-thickness, fasciocutaneous scalp flap to cover the nearby reconstructed skull, as first described by our team in 2016.[11] With this, local scalp flap(s) are manipulated to provide healthy, vascularized tissue coverage, and at the same time, provide increased scalp laxity contributing to a tension-free closure. To achieve this, either a bi-pedicle advancement flap (Fig. 1) or single-pedicle transposition flap (based on superficial temporal or occipital vessels) (Fig. 2) is dissected in a subgaleal plane.[13] Flaps are strategically designed so that the final position of the grafted donor site is both distant and posterior to the cranial implant—thereby minimizing potential contamination and visibility of the nonhair baring graft while in frontal view (Figs. 1 and 2).

In patients where the residual scalp defect spans exposed cranial bone, the local donor site is prepped with cortical bone debridement (ie, round-cutting burr) to stimulate punctate bleeding. Alternatively, in instances where the residual scalp defect spans intact muscle or vascularized pericranium, no donor site preparation is required (this is preferred, when and if possible, vs bare cranial bone). Next, a flexible template of the residual scalp defect is cut to shape, and then transferred to the donor site and traced with marking pen—preferably from either the infra-umbilical abdomen/groin area (when patient is supine) or the upper posterior thigh (when patient is in prone position). To account for primary contraction of the FTSG, a slightly larger graft is harvested using a scalpel, forceps, local anesthesia, and bovie cautery. The FTSG donor defect (from abdomen or thigh) is closed primarily in linear fashion—which is much more esthetically pleasing, as compared harvesting an STSG with a dermatome.

After FTSG harvest is completed by hand, the under surface of the graft is trimmed with scissors to assure that all subcutaneous fat has been removed. The FTSG is then pie-crusted with a No 10 scalpel to allow for possible fluid drainage (Fig. 2). Next, the FTSG is sutured into the local donor scalp defect using 3-0 chromic suture in running-locking fashion. Antibiotic ointment and sterile petroleum gauze (Xeroform; Covidien, Dublin, Ireland) is used to cover the graft and serve as bolster in combination with surgical foam (Rest On Foam; 3M, Maplewood, MN), which is carefully stapled to the surrounding scalp. The bolster is removed in 1 to 2 weeks depending on the size or condition of the recipient bed during outpatient follow-up. Notably, no adjunctive wound care measures or equipment, such as a wound vacuum device has been required.

RESULTS

Patient Demographics

A total of 33 patients were identified, all of whom underwent combined skull and scalp reconstruction using the FTSG method described here. Average follow-up time was 1.8 years and 19 of the 33 patients (58%) were female. Mean patient age was 56.8 years (range 24–92, standard deviation 18.5). Preoperative patient characteristics are described further in Table 1. Overall, 25 (75%) patients presented with "high complexity" scalp defects, as they each had >5 previous surgeries (n = 23, 70%) and/or had received radiation therapy (n = 15, 45%) prior to reconstruction. The most common underlying pathology necessitating surgery was tumor (n = 21, 63%), followed by trauma (n = 5, 20%).

Scalp defect characteristics and variances are presented in Table 2. As previous authors defined scalp defects based on size, we similarly classified our patient cohort with those defects between 9 and 50 cm^2 defects as "medium-sized" defects, and defects >50 cm^2 as "large-sized" defects.[5,8,9,14] With this type of classification, 12 (36%) had large-sized scalp defects and 20 (60%)

TABLE 1. Preoperative Patient Characteristics

Variables	Value	% (n = 33)
Average follow-up duration, y	1.8	
High complexity scalp (previous surgeries > 5)	13	39.39
Prereconstruction recipient site Radiotherapy	15	45.45
Relevant medical history for each patient		
No relevant medical history	21	63.64
Anticoagulant therapy	6	18.18
Diabetes mellitus	3	9.09
Smoking	2	6.06
Sturge–Weber syndrome	1	3.03
Initial pathology		
Tumor	21	63.64
Trauma	5	15.15
Infection	3	9.09
Congenital hydrocephalus	1	3.03
Cerebral aneurysm	1	3.03
Functional neurosurgery	1	3.03
Arteriovenous malformation	1	3.03

TABLE 2. Scalp/Skull Defect Characteristics

Variables	Value	% (n = 33)
Defect type		
Hard tissue defect	25	75.76
Soft tissue defect	8	24.24
Recipient defect size		
Large ($\geq$50 cm^2)	12	36.36
Medium ($\geq$9 cm^2)	20	60.61
Graft recipient site substrate		
Over muscle/pericranium	21	63.64
Over bone	12	36.36

had medium-sized defects. Twenty-one (64%) graft beds consisted of intact muscle/pericranium, while the remaining 12 (36%) grafts were placed over bare cranial bone.

Final FTSG take results are summarized in Table 3. In 27 of the 33 patients (82%), graft take at follow-up was 100%. Two (6%) patients were found to have graft take of 95%, while 2 (6%) patients had graft take of around 90%. In the latter patients, the 5% to 10% residual area of exposed bone healed uneventfully by secondary intention. In total, this equates to a 94% success rate for all FTSGs presented in this consecutive series. The unsuccessful group included 2 patients. One (3%) patient, who was radiated prior to the reconstruction stage, lost 50% of his graft due to necrosis. The other patient (3%), for whom did not previously receive irradiation, failed completely necessitating the need for free flap for coverage. Of the 15 patients who received scalp irradiation prior to reconstruction, 13 (87%) had graft take of 100%, while 1 patient (7%) had graft take of 95% and the second patient (7%) is the one previously noted—who experienced graft failure necessitating free tissue transfer.

TABLE 3. Graft Success Rate

Variables	Value	%
Overall take (n = 33)		
100% Take	27	81.82
95% Take	2	6.06
90% Take	2	6.06
Failure (<90%)	2	6.06
Graft take in radiated scalp (n = 15)		
100% Take	13	86.67
95% Take	1	6.67
Failure (<90%)	1	6.67

Due to the overall high rate of graft take found within our study, no risk factors were identified to statistically correlate with graft failure including: radiation therapy, size of cranial defect, previous infections, co-morbidities, and/or number of previous neuro-cranial surgeries. In addition, the success rate did not differ whether the graft was inset over bare cranial bone versus over vascularized muscle/pericranium. Furthermore, the size of the FTSG did not correlate with either success or failure.

DISCUSSION

In the spectrum of neuroplastic and reconstructive surgery, one must aim for all cranioplasty patients to receive tension-free scalp closures. This can be accomplished by way of local fasciocutaneous flaps, which are essential to incisional healing and long-term cranial implant protection. In parallel, numerous techniques of various complexities have also been described by others when in similar circumstances. These successful methods include staged tissue expansion, healing by secondary intention with daily dressing changes, STSGs, local/regional scalp flaps, and free tissue transfer.[8,9,15] Each of the aforementioned methods has their own set of advantages and disadvantages.

Staged tissue expansion has been used to successfully repair large scalp defects; however, this process requires numerous clinical visits, can be a painful process for the patient prior to the second (delayed) operation, requires a lengthy interval period, causes abnormal thinning of the scalp (related to pressure/stretch), and accompanies significant risk for infection—especially concerning when one plans to use alloplastic cranial implants secondarily.[16–18] For example, Cunha et al[19] reported a 20% complication rate in scalp reconstruction using staged tissue expansion. In parallel, tissue expansion, in the setting of pre-existing cranial defects, can also cause pressure to the underlying dura/brain.[20,21] Healing by secondary intention is also a lengthy process, which requires time-consuming wound care resources, risk of scaring/tension, risk of infection contamination, and impending implant failure.[20]

Free tissue transfer is widely regarded as the preferred method of repair for large-sized scalp coverage in the setting of cranioplasty reconstruction.[22] Numerous patient series have demonstrated successful treatment with low complication rates.[4,23–28] However, free tissue transfers require a timely commitment, mandates a labor-intense surgery, accompanies significant perioperative risk for failure/take back, and requires a much-longer prolonged postoperative course/intensive care unit stay. In addition, it often creates a visually deforming, demarcated, bulky flap area with alopecia and color mismatch—and often requires revision surgery.[1,29,30]

Skin grafting for medium- to large-sized scalp defects has widely been disputed in the literature due to reported poor wound healing and complications.[2,4,9,14] However, these complication rates appear to be inconsistent with our experience, and thus examined further.[31] In our series of medium-to-large FTSGs, in the setting of concomitant cranioplasty, graft failure (defined as <50% take or less) only occurred in 2/33 patients (6%). In fact, this complication rate is quite comparable to similarly sized defects treated with free tissue transfer.[23]

Likewise, multiple authors have specifically condemned reconstruction with FTSGs over burred bone due to poor outcomes.[2,9,14,32,33] However, our team has observed better results with FTSGs over bone versus that seen with split-thickness grafts on bone. Furthermore, the 2-step procedures often reference and require an initial stage of granulation tissue growth in the wound bed prior to skin grafting.[2,9,14] Although recent patient series have demonstrated great success, we have not found it necessary to have granulation tissue present on the bare bone.

For example, an 11-patient series using medium-sized full thickness scalp defects (6–50 cm^2 mean 24.5 cm^2), treatment with STSGs (after milling of the outer table of the skull) resulted in complete wound healing without complication in all 11 patients.[34] However, in the senior author experience, the STSG has been found to be less durable and its long-term reliability inferior to FTSGs—when faced with injury caused by inadvertent trauma. Furthermore, the predominantly elderly patients (in this series) expressed greater preference for faster recovery over better cosmetic results (achieved through multiple surgical interventions like free flaps or staged tissue expansion).[34] As such, the results of our study further reinforce that single-stage full-thickness skin grafting (over burred calvarium or muscle/pericranium) can successfully cover local scalp defects with low complication rates, and that another option exists beyond STSG. Instead, an FTSG is much more esthetic, has better resistance to incidental trauma, and in some instances, can even support hair follicle growth.[35]

For defect coverage in irradiated patients following adjacent tissue transfer, the use of skin grafts has been reported to yield poor results.[8,36] In our series (n = 15), 13 (87%) had 100% graft take following irradiation, while only a single patient had graft take <50%. These results suggest that FTSGs may be a safe choice for local defect coverage following scalp radiation therapy, especially in those patients with co-existing co-morbidities for whom prolonged anesthesia is considered suboptimal.

Regardless of one's surgical training, medium- to large-sized scalp defects are traditionally considered best served with a free flap—since the traditional understanding is that grafts are esthetically inferior and less dependable for full-thickness scalp defects.[2,18] However, PubMed search yielded no large series esthetic comparison of free flaps versus FTSGs in instances of medium- to large-sized full-thickness scalp defects. In fact, esthetic analyses of free tissue transfer patients have noted a "noticeably bulky appearance," which unfortunately persists until either the flap muscle atrophies or revision surgery for fat debulking.[1,29] In a review of 84 oncologic patients undergoing free flap scalp reconstruction, 19 (22%) patients sought additional surgeries for esthetic improvement.[29] In the absence of a demonstrated advantage, full-thickness skin grafting—from an esthetic perspective—should not be dismissed as an inferior cosmetic alternative. In our own cohort, we have found that the characteristic bulkiness seen in free tissue transfer is much more cosmetically inferior to the immediate smooth contour of FTSGs. Notably, the area of FTSG continuously contracts and becomes less noticeable over time—especially when the surrounding, anterior scalp hair grows back covering the grafted parietal/occipital areas. This occurs since we strategically plan our FTSGs such that the recipient area is in a concealed location and that the patient's natural hairline remains undisturbed (Fig. 1). A weakness of our study is its limited size and length of follow-up. As such, we plan to perform further studies examining the long-term, esthetic outcomes of our grafted cranioplasty patients for a more definitive comparison.

CONCLUSION

We present here a preliminary series of neurosurgical patients with medium- to large-sized scalp defects who were successfully treated with full-thickness skin grafting (onto muscle, pericranium, or bare calvarial bone) following adjacent tissue transfer and cranioplasty. In contrast to previous studies that have reported inconsistent success with skin grafting, we present here an important technique for the neuroplastic surgeon's tool box—in an attempt to avoid the accompanying morbidity and recovery time required for free-tissue transfer. Full-thickness skin grafts, in the correct setting, offer consistent reliability and excellent cosmetic results—even in the highly complex, cranioplasty patient population.

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