Vascularized Calvarial Bone Flaps and Midface Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Identify the fascial layers of the temporalis region. 2. Understand the three-dimensional nature of the orbit and upper maxillectomy defects. 3. Understand the surgical harvest of temporalis flaps and temporoparietal flaps with vascularized bone. 4. Appreciate preoperative risk factors and postoperative complications.

Background: Although vascularized calvarial bone grafts were originally explored for use in reconstruction of midface hypoplasia defects, they offer significant value in application to oncologic reconstruction of the midface.

Methods: A review of eight cases of midface reconstruction using vascularized calvarial grafts was performed to illustrate the versatility and dependability of these flaps.

Results: Adequate bony and soft-tissue contours were achieved with no clinical evidence of bone graft resorption. No immediate postoperative complications including infection and hematoma or seroma formation were noted. One patient experienced a delayed sinusitis from a blocked duct.

Conclusions: The use of vascularized calvarial grafts supported by temporoparietal fascia, combined deep temporal fascia, and temporalis muscle provides excellent soft-tissue coverage and adequate bone stock for reconstruction of complex defects. Maintaining vascularization of the bone graft not only resists infection but also opposes resorption associated with nonvascularized grafts, particularly those in compromised wounds. (*Plast. Reconstr. Surg.* 122: 10e, 2008.)

There has been a resurgence in the description of regional flaps for reconstruction of the midface. These include the temporoparietal fascial, combined deep temporal fascial, and temporalis muscular flaps, all three of which have been used with and without associated bone grafts.[1] The use of vascularized calvarial bone grafts has previously been described in the literature in association with midface hypoplasia reconstruction.[2] The rise in prominence of osteodistraction for reconstruction of midface hypoplasia has decreased the necessity for flap reconstruction. However, regional calvarial grafts still play important roles in reconstruction of the maxilla, the floor of the orbit, and maxillectomy defects.[3,4] In particularly, they are important in acquired defects from oncologic resections such as maxillectomy, lateral orbital rim, and zygoma.

ANATOMY

The temporoparietal region consists of seven anatomical layers: (1) skin and subcutaneous tissue; (2) temporoparietal fascia; (3) subgaleal fascia; (4) combined deep temporal fascia, consisting of the fusion of two superficial and deep components; (5) temporalis muscle; (6) calvarial periosteum; and (7) calvarial bone (Fig. 1).[5] The superficial temporal fascia (temporoparietal fascia, epicranial aponeurosis) is part of the subcutane-

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Received for publication June 19, 2006; accepted December 12, 2006.
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DOI: 10.1097/PRS.0b013e3181774115

Disclosure: *None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this article.*

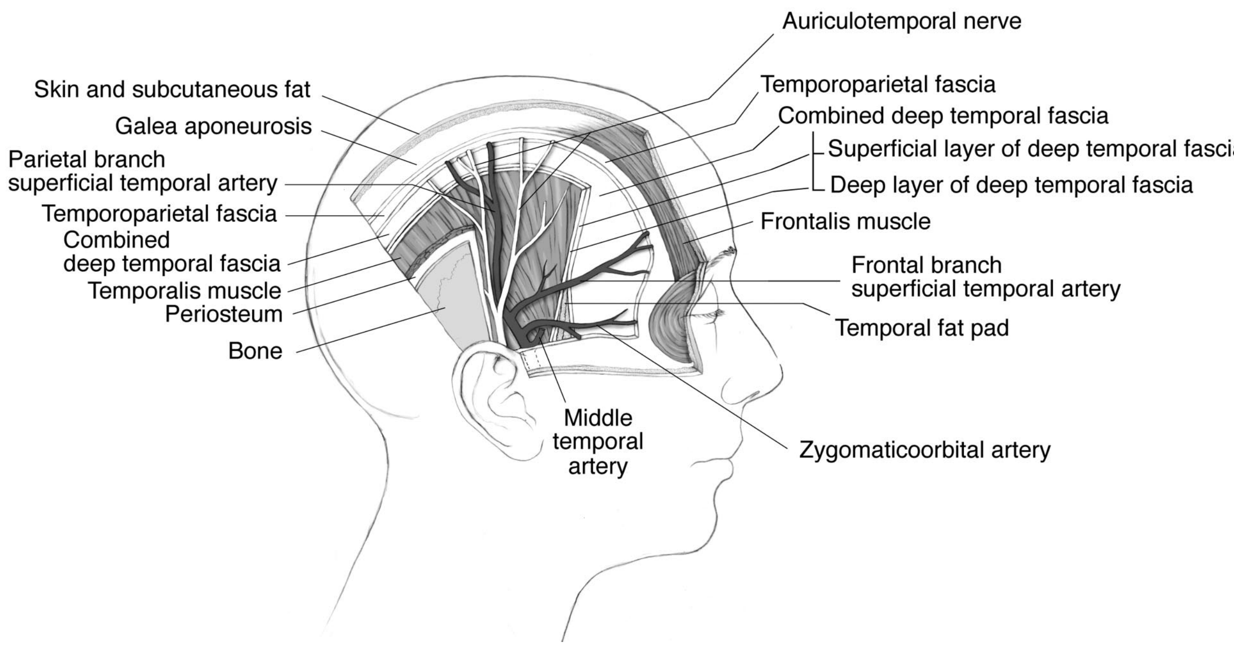

Fig. 1. Layered anatomy of temporoparietal region.

ous musculoaponeurotic system and is continuous with the galea above and the superficial musculoaponeurotic system layer of the face below. The deep temporal fascia or fascia of the temporalis muscle is separated from the superficial fascia by an avascular plane of loose areolar tissue, and invests the temporalis muscle down to the zygomatic arch. It attaches to periosteum around the muscle margins. The rich availability of flap pedicles that all coalesce to the periosteum makes the temporoparietal region an excellent donor site.

In the temporoparietal region, three vascularized calvarial flap types have been described.[1,6] The temporoparietal fascial flap is the most superficial, sustained by the superficial temporal artery as its vascular pedicle. Existence of perforators of the branches of the superficial temporal artery into the pericranium and underlying calvaria in the temporoparietal region allows for concomitant harvest of vascularized bone in support of this fascial flap[7] (Fig. 2).

The second vascularized calvarial flap in this region is the combined deep temporal fascial flap, consisting of two fused superficial and deep components.[2] Note the combined deep and superficial temporal fascia only extends over the scalp to approximately 2 cm above the orbital rim. The vascular supply is provided by the middle temporal artery, arising proximally from its origin at the superficial temporal artery and entering the superficial temporalis fascia above the superior border of the zygomatic arch. This flap has an arc of rotation shorter than that of the temporoparietal fascial flap (Fig. 2).

The temporalis myo-osseus flap is the third type of regional flap. Its components, the temporalis muscle, the distal pericranium, and the underlying bone, are transferred as one unit.[3] The temporalis muscle has two dominant vascular pedicles, the anterior and posterior deep temporal arteries. These branch off from the maxillary artery and penetrate into the deep surface of the muscle (Fig. 2).

The bone harvested in such flaps may be the outer table or full-thickness bone. Use of the parietal bone is particularly favorable, as the midline involvement of the underlying sagittal sinus must be avoided. It is important to ensure adequate maintenance of bone thickness, which gradually tapers inferior to the superficial temporal line, by making cuts in the cancellous bone that preserve the entire thickness of cortex.

In this article, we describe the versatility of vascularized temporoparietal bone grafts for midface reconstruction following head and neck resection. We have used flaps consisting of temporoparietal fascia, combined deep temporal fascia, and/or portions of temporalis muscle, all with associated vascularized calvarial bone. We illustrate modifications of these flaps for use in three-dimensional orbital reconstruction. We also demonstrate their use in reconstruction of the external mastoid wall after temporal bone resection.

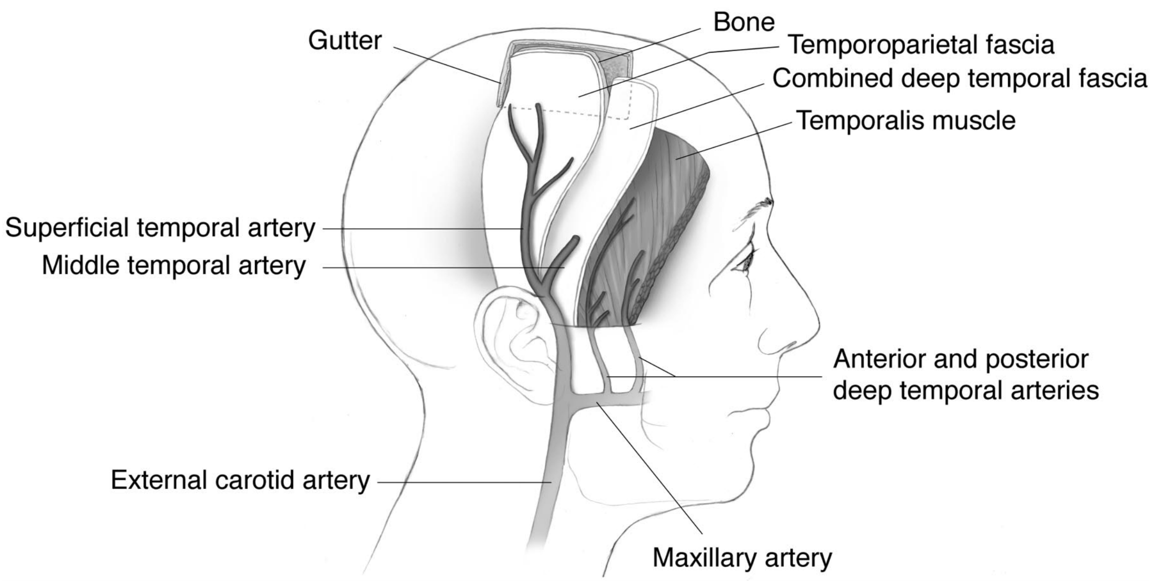

Fig. 2. Anatomy of vascularized calvarial bone graft based on temporoparietal fascia, combined deep temporal fascia, and temporalis muscle flaps. Corresponding vascular pedicles are depicted.

PATIENTS AND METHODS

Harvest of all types of vascularized calvarial grafts begins with a preauricular incision that extends superiorly into the temporal hairline. The incision may then be arched forward in continuity with a bicoronal approach or zigzagged for camouflage within the associated hairline. Care is taken to avoid damage to the hair follicles to prevent postoperative alopecia. The skin flaps are rotated anteriorly and posteriorly, and the incision is carried down to the plane of the temporoparietal fascia. The decision regarding the level of flap elevation is made. The pericranium is then exposed superiorly. Next, the flaps are harvested with their respective pedicles: the temporoparietal fascia with a branch of the superficial temporal artery, the combined deep temporal fascia with a branch of the middle temporal artery, or the temporalis with the deep temporal artery branches.

The pedicle is dissected onto the periosteum overlying the calvaria. Multiple calvarial strips are dissected out with intact periosteum and limited to 2 to 3 cm in width to ensure integrity during harvest. Multiple strips are required for complex three-dimensional reconstructions. A gutter is created with a round burr and the outer calvarial plate is elevated with an osteotome or an angled blade. The proximal cut under the pedicle is the hardest to make, and care must be taken not to back into the soft tissue. The pedicle and bone are rotated down to the recipient site. The calvarial bone can be sectioned to reconstruct multilinear defects. Fixation at the recipient site is completed with standard plate fixation. The donor defect in the bone is repaired with a hydroxyapatite fill material. If the temporalis is harvested, a silicone block is carved to fill the donor-site defect. It is important to note that in some defects with optimal blood flow, nonvascularized bone grafts may be used, which can revascularize adequately by diffusion from surrounding tissue. However, calvarial bone with vascular perforators from periosteal attachments is required to adequately reconstruct cases of irradiated or heavily scarred beds with disrupted vascular supply seen in the oncology field (Table 1).

A review of eight cases of head and neck reconstruction between 1999 and 2006 using vascularized calvarial bone flaps was performed. Seven men and one woman with ages ranging from 39 to 82 were included. Before reconstruction, seven patients had undergone tumor resection; one had sustained traumatic injury. Three patients received radiation before reconstruction. Four illustrative sample cases are provided.

CASE REPORTS

Case 1

A 41-year-old man presented with a benign myxoma over the right maxilla with invasion of the periorbit and erosion into the zygoma. Resection entailed removal of the middle portion of the superstructure of the maxilla, including the orbital floor and the orbital rim, leaving the sinus exposed in two planes with no soft tissue. The middle third of the temporalis with a 5 × 4-cm outer cortical calvarial graft was harvested with a deep temporal artery perforator serving as the vascular pedicle. The integrity of the deep temporal fascia to the pericranium was maintained to preserve robust vascularization of the bone graft. The calvarial graft was divided in two and passed beneath the zygomatic arch for use in two-plane reconstruction. One plane was used to reconstitute the floor of the orbit, and the other was used to rebuild the anterior maxilla[6] (Figs. 3 and 4).

Case 2

An 82-year-old man had undergone irradiation with wide surgical resection of the postauricular skin and deep tissue and the associated outer table of the mastoid for squamous cell carcinoma. The resultant irradiated calvarial defect with exposure over the mastoid measured 4 × 4 cm. A temporoparietal fascial flap based on a defect-matched section of temporoparietal bone was created, with fascial and bony apposition left intact to maintain vascularization. The bony portion was inserted into the defect and the periosteum sutured to mastoid fascia. The overlying fasciocutaneous portion of the flap was then reflected to cover the conchal defect (Fig. 5).

Table 1. Indications for Vascularized Calvarial Bone Grafts

Indications
Extreme trauma with significant vascular compromise (e.g., gunshot wound)
Irradiated beds
Multiplanar exposure to sinus with high risk of infection
Multiple oncologic resections with no soft-tissue support

Case 3

A 75-year-old man had undergone extended resection of the left zygomatic arch and trimalar complex followed by irradiation for invasive basal cell carcinoma. The patient experienced significant loss of bulk and disruption of contour of his left face with a 10 × 12-cm defect. Reconstruction was performed using outer table parietal bone with a combined temporoparietal fascia and temporalis muscle flap based on the superficial and deep temporal arteries. A cervicofacial rotational flap provided superimposed soft-tissue coverage (Figs. 6 and 7).

Case 4

A 47-year-old man with a left maxillary squamous cell carcinoma along the lateral aspect of the orbital rim had undergone multiple prior resections, including prior maxillectomy and subsequent irradiation resulting in significant ectropion. Inferior and lateral orbital wall deficits measuring 4.5 × 3 cm and 3 × 2 cm, respectively, were reconstructed using a temporoparietal fascial flap based on a 6 × 2-cm outer calvarial temporoparietal bone flap. The reconstructed orbit was then used as a platform for soft-tissue revision of the lid (Figs. 8 and 9).

RESULTS

Average postoperative follow-up period was 56 months. In all cases, there was no clinical evidence of postoperative bone graft resorption. In one patient, dural penetration occurred without subsequent cerebrospinal fluid leakage. There were no immediate or delayed neurologic deficits. There were no seromas, hematomas, or postoperative infections. Excellent bony and soft-tissue contours

Fig. 3. Case 1. (*Left*) Preoperative view of a 41-year-old patient who had undergone reconstruction with a temporalis flap based on vascularized calvarial graft. The patient had previously undergone resection for a right maxillary and zygomatic myxoma that left a defect with sinus exposure and no soft tissue. (*Right*) Nine months after reconstruction.

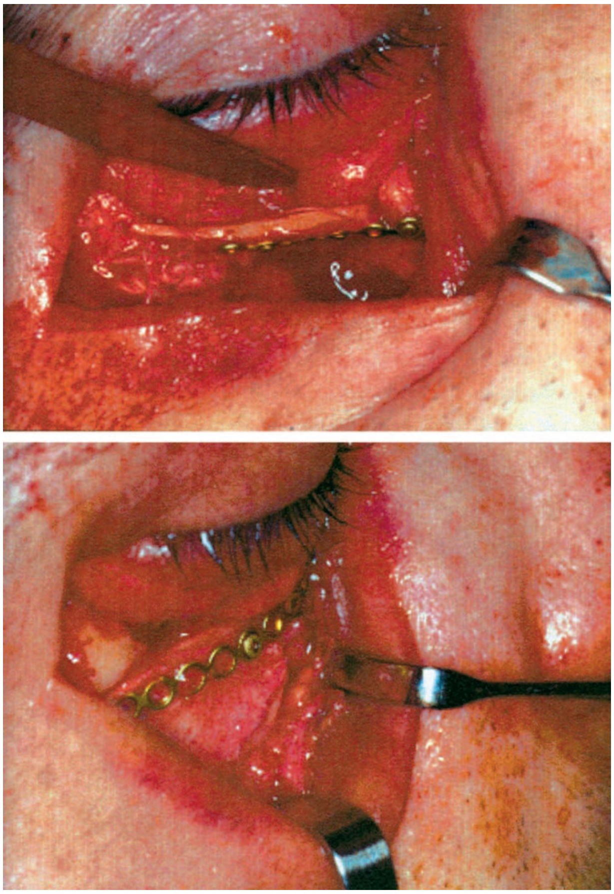

Fig. 4. Case 1. Intraoperative view of patient undergoing temporalis myo-osseous flap reconstruction. A two-plane reconstruction of maxillary and zygomatic defects using calvarial bone is shown. Note that the floor of the orbit is repaired with one piece of bone (*above*) and the anterior orbital wall is repaired with another (*below*).

were achieved. One patient required a secondary orbital graft for volume-deficient enophthalmos. At reexploration, the bony orbit was viable and fully intact despite being in contact with the maxillary sinus. One patient required secondary soft-tissue fill; the bone was fully incorporated. Another patient experienced a delayed sinusitis from a blocked duct (Table 2).

DISCUSSION

Free versus Vascularized Bone

Vascularized calvarial flaps have been shown histologically and anatomically to be superior to free calvarial grafts. Vascularized flaps retain viable osteocytes, maintain greater osseous mass, minimize resorption, achieve reliable, early bone integration, and are associated with low rates of infection.[2,8–14]

Calvarial versus Other Bone Grafts

Successful head and neck reconstruction has been described frequently using free grafts of other bony origins including iliac crest, fibula, scapula, radius, and rib.[15,16] Although revascularization of such grafts presumably affords the same benefits as pedicled calvarial grafts as described above, revascularization necessitates microvascular techniques requiring specialized equipment and training, with extended operative time in an adjacent site. The vascularized calvarial graft offers the additional advantage of minimal donor-site morbidity.

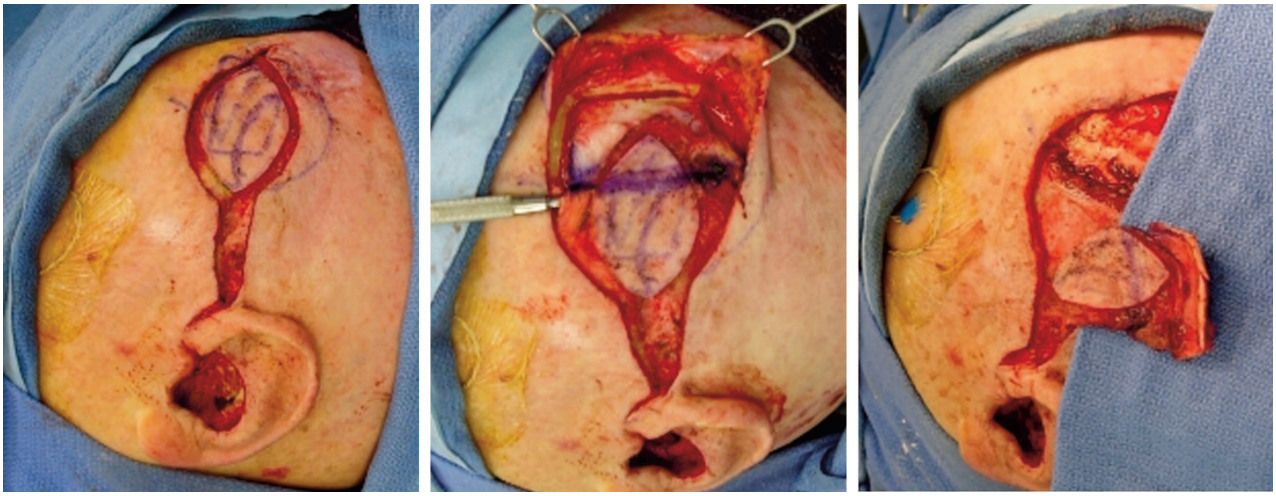

Fig. 5. Case 2. Sequence of intraoperative views of an 82-year-old patient undergoing reconstruction using a temporoparietal fascial flap in association with a vascularized calvarial graft. The patient had undergone multiple prior resections for invasive squamous cell carcinoma of the concha. (*Left*) The temporoparietal fascia is exposed. (*Center*) The calvarial bone harvest location is marked. A gutter is created to facilitate outer table harvest. (*Right*) Elevation of vascularized temporoparietal bone based distally on temporoparietal fascia is achieved.

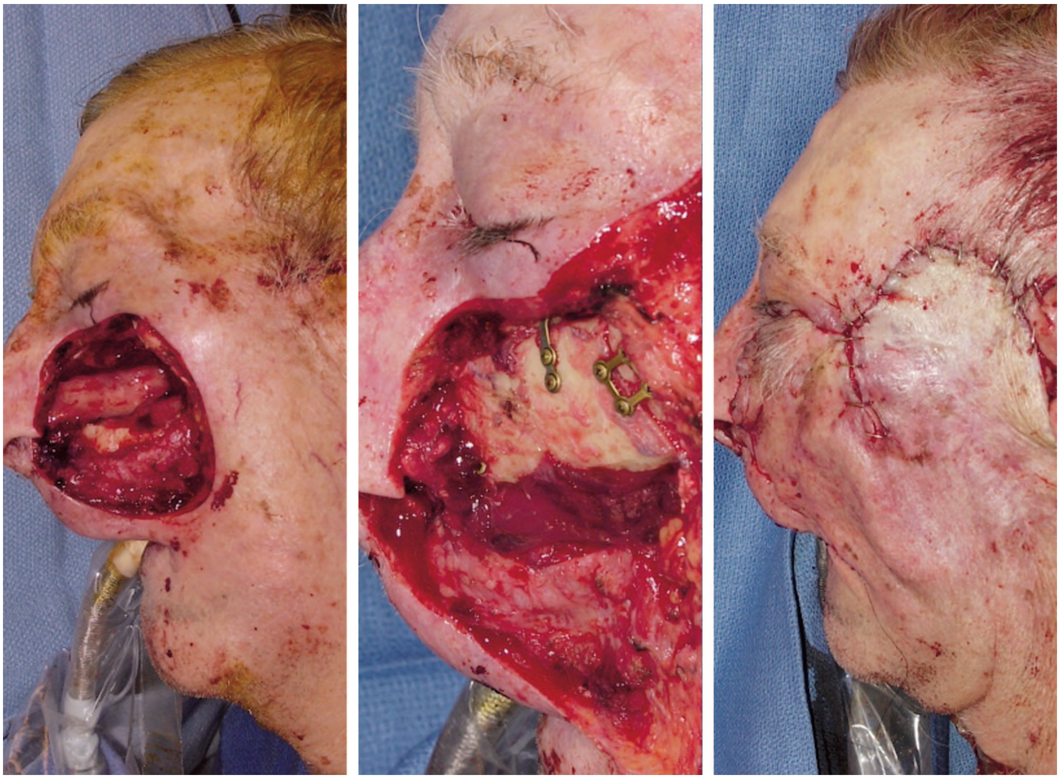

Fig. 6. Case 3. Intraoperative views of a 75-year-old man undergoing temporoparietal fascia and temporalis muscle flap reconstruction. The patient had undergone resection of the left zygomatic arch secondary to basal cell carcinoma, with subsequent irradiation.

Fig. 7. Case 3. Three months after reconstruction.

Pedicle Selection

Selection of the pedicle involves multifactorial considerations. The temporoparietal fascial flap has the longest pedicle length and arc of rotation, allowing the greatest flexibility in its application. The temporalis flap, in contrast, provides the largest amount of soft-tissue bulk, which is frequently necessary after extensive oncologic resection. It is necessary to harvest the temporalis muscle when there is significant bone and soft-tissue defects as exemplified in this article by three cases of maxillary sinus defects and one case of a conchal cartilage and skin defect. However, should the muscle be used in its entirety, the resultant deficit over the superior temporal fossa requires additional reconstruction. We have found soft-grade silicone blocks to be the most successful method of donor-site reconstruction. Hydroxyapatite bone substitute is excellent for outer calvarial table fill but crumbles and extrudes if used for soft-tissue fill.

When vascularized calvarial flaps are used for reconstruction following oncologic surgery of the head and neck, variable local anatomy is often

Fig. 8. Case 4. (*Left*) Preoperative view of a 47-year-old patient who underwent reconstruction with a vascularized calvarial graft based on a temporoparietal fascial flap. The patient had previously undergone resection for a left maxillary squamous cell carcinoma and subsequent irradiation. (*Center*) Six months and (*right*) 2 years after reconstruction.

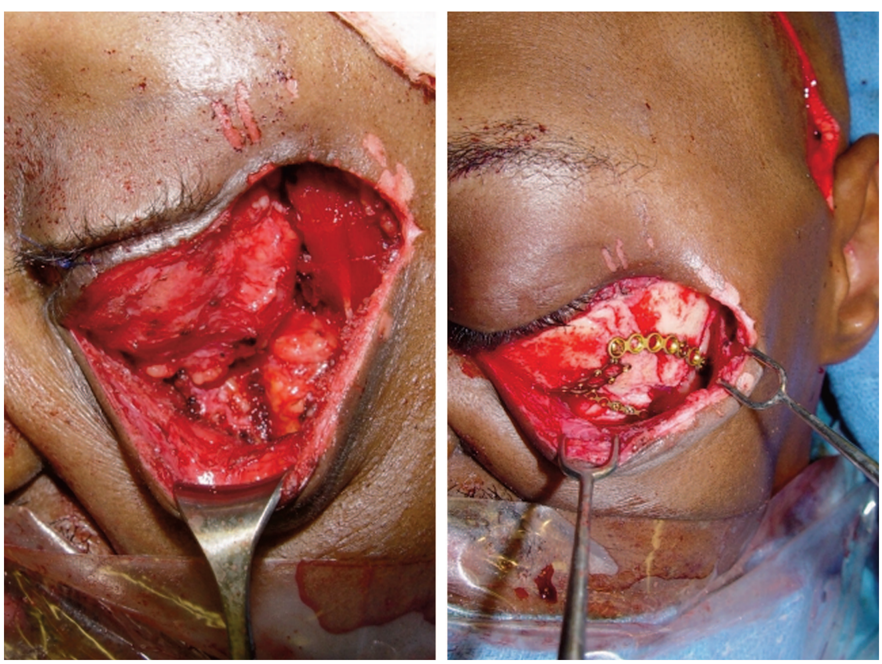

Fig. 9. Case 4. Intraoperative views of vascularized calvarial bone grafting with temporoparietal fascial flap reconstruction.

encountered as a result of prior operations. Vascular compromise such as ligation of the deep temporal arteries or the internal maxillary artery during posterior maxillectomies renders the temporalis pedicle unusable, requiring incorporation instead of the combined deep temporalis fascia. In any case, identification of the intact vascular pedicle by Doppler should precede elevation of any of the three vascularized calvarial flaps described.[17]

Bone Harvest

Prior descriptions of calvarial bone harvest have mainly involved younger patients undergoing reconstruction of congenital craniofacial syndromes. In these patients, the soft, immature dip-

Table 2. Patient Summary

Patient	Age (yr)/Sex	Lesion	Defect	Calvarial Graft Size (cm)	Graft Pedicle	Follow-Up (yr)	Complications/ Revisions
1	41/M	Myxoma	Right maxilla, zygoma, orbital floor, orbital rim, sinus exposure in two planes	5 × 4	Temporalis and deep temporal fascia	6	None
2	82/M	SCC	Left pinna, mastoid after irradiation	4 × 4	Temporoparietal fascia	4	None
3	75/M	BCC	Left zygoma, trimalar complex after irradiation	10 × 12	Temporalis and temporoparietal fascia	4	None
4	47/M	SCC	Left maxilla, orbital rim, inferior orbital wall, lateral orbital wall after irradiation; status post multiple previous resections	6 × 2	Temporoparietal fascia	2.5	Orbital volume revision
5	59/F	Myxoma	Left maxilla, orbital floor, orbital rim with significant sinus exposure	6 × 4	Temporalis	7	None
6	39/M	Gunshot	Left maxilla, zygoma, orbital floor	2.5 × 1	Temporoparietal fascia	4	None
7	77/M	BCC	Left superior orbital wall, lateral orbital wall, frontal bone with previous resections	6 × 3	Temporalis	4	None
8	70/F	Sinus CA	Left infraorbital rim with sinus exposure	3 × 2	Temporoparietal fascia	2	Sinusitis

M, male; F, female; SCC, squamous cell carcinoma; SCC, squamous cell carcinoma; CA, cancer.

loic space between the inner and outer calvarial tables allows for in situ harvest of the outer table with ease. In older patients, however, access to such a space is more difficult, and harvest is facilitated by first creating a gutter bordering the graft. Subsequent harvest of the outer table with an osteotome is completed.[18] Calvarial bone may be brittle and at times may break off in slivers during harvest. However, as long as they remain attached to periosteum, the overall shape and vascularization will be maintained.[19] Despite the 10 percent risk of dural exposure during bone harvest procedures, the associated incidence of neurologic sequelae is as low as 1 percent.[20]

Orbital Reconstruction

Vascularized temporoparietal calvarial grafts are excellent options for orbital reconstruction.[21] Avoidance of dystopia requires complex three-dimensional reconstruction.[22] To achieve this goal, the harvested bone may be split and used in multiple planes while remaining attached to one vascular pedicle, thus allowing single-procedure reconstruction of the orbital floor and rim using a single donor site.

Maxillary Reconstruction

Maxillary reconstruction presents a particularly ideal setting for use of vascularized calvarial flaps. Nonvascularized bone grafts survive through gradual angiogenesis arising from the recipient bed into the transplanted tissue. The maxillary sinus and the mastoid air cells, however, do not provide adequate tissue surface for the invasion of nutrient vessels into the flap. Thus, in circumstances where the flap is to be exposed to air space rather than tissue bed, flap survival is maximized by maintaining its intrinsic blood supply.[6]

Reconstruction of Irradiated Beds

Irradiated tissue provides a poor recipient bed for nonvascularized bone transfer. Growth of new blood vessels and osteogenic cells is hampered, leading to increased bone resorption.[15] When transferred to an irradiated wound bed, vascularized bone grafts with viable osteoprogenitor cells and intrinsic blood supply retain osteogenic potential. Earlier callus formation, stronger union, and decreased resorption are the consequent benefits.[12,23]

Traumatic Defects

Traumatic defects amenable to reconstruction include avulsive injuries, abrasive road injury to the zygoma, and gunshot wounds, particularly when the vector of injury is from intraoral crossing the palate out. These injuries would be ideal for bone with soft-tissue repair.

CONCLUSIONS

Vascularized calvarial bone grafts add significantly to head and neck oncologic reconstruction. The benefits of vascularized bone include resistance to infection and earlier recipient-site integration. The multiple pedicle options allow a spectrum of flap lengths and bulk that may be tailored to the defect size. These flaps are suitable for reconstruction of the zygomatic arch, maxilla, and mastoid. The potential for the three-dimensional reconstruction of the orbit is also excellent.

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CPT CODING FOR CALVARIAL BONE FLAPS

15732	Muscle, myocutaneous, or fasciocutaneous flap; head and neck
20902-51	Bone graft, any donor area; major or large

- These flaps are axial pattern flaps, based on branches of the temporal arteries. These axial pattern fascial and muscle flaps are described with CPT code 15732.
- Code 15732 is global and includes incision, preservation of the vascular pedicle(s), elevation of the flap, transposition, and closure of the donor site.
- The axial pattern fascial and muscle flap codes do not include bone harvest, which is separately reported with code 20902.
- These codes do not include the primary ablative procedures. Resection procedures prior to bone flap reconstruction are separately reported.

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