

Use of an Inverted and Segmented Galea-Calvarial Flap for the Simultaneous Reconstruction of the Frontal Sinus and Forehead: A New Supplementary Method of Reconstructive Cranial Surgery

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We report on a new technical method of using an inverted and segmented galea-calvarial flap for simultaneous reconstruction of the frontal sinus and forehead. A 73-year-old man presented with the production of pus at the forehead, in which the frontal sinus had been involved 6 years postoperatively. The patient underwent surgery with our new simultaneous technique. During the 7 years of follow-up after this reconstructive surgery, no recurrence of surgical wound problems was noted.

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Key words: partial cranioplasty, inverted and segmented galea-calvarial flap, anterior skull base reconstruction, bone-bearing flap, vascularized bone flap

Introduction

Surgical errors involving the frontal sinus can result in focal infection of the forehead¹. During endoscopy to confirm drainage to the paranasal sinuses or during septectomy to drain the contralateral nasofrontal cannula, the following factors are important for controlling infections and avoiding postoperative complications: isolating the frontal sinus and epidural spaces¹, avoiding dead spaces², avoiding the use of foreign materials³, treating skin ulcers with vascularized monopodicle flaps¹ or bipedicle flaps⁴, and properly closing the damaged frontal sinus mucosa. Case reports of suppurative complications describe symptoms only several years after neurosurgical interventions with foreign materials⁵. Once the infections are controlled, difficult reconstructive procedures are usually performed within 6 months. Bone can be reconstructed with free calvarial autografts and foreign materials, such as titanium mesh. However, because vascularity remains absent, such grafts cannot control infection as well as vascularized grafts can.

We describe a simple yet successful method of forehead reconstruction with an inverted and segmented galea-calvarial flap, which enables the frontal sinus to be

closed and isolated via a vascularized galea. This method of reconstruction also eliminates dead spaces and simultaneously maintains the vascularity of the outer calvarial graft with a single operation. Our method allows ideal forehead contours to be designed without the need for foreign materials or free grafts.

Case Illustration

History

In June 2001 a falx meningioma was removed under a frontal craniotomy in a 73-year-old man. In the reconstruction process, original skull, cut into 2 pieces, were used together with titanium mesh and plates. In August 2006, the patient visited a local clinic to report erythema of the forehead with serous fluid. Frontal sinusitis was diagnosed, and because antibiotic therapy had failed, the patient was referred to our hospital. We noted a dermal fistula and skin ulcer (**Fig. 1a**), beneath which was a titanium mesh that had been used to replace much of the frontal bone (**Fig. 1b**). In November 2006 we performed corrective surgery in which the local skin flap method would be used and the titanium mesh would be removed with the patient under local anesthesia. During

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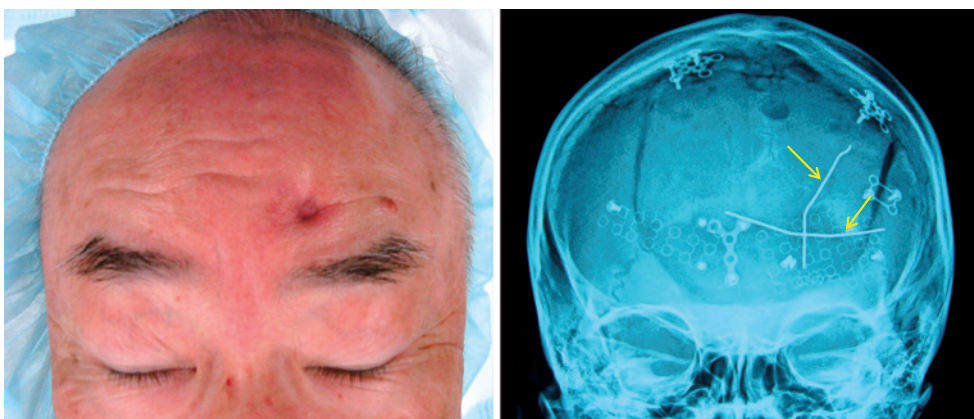


Fig. 1 The patient presented with erythema and the production of serous/infectious fluid on the forehead which revealed a dermal fistula and a skin ulcer (left).

A radiograph of the skull (right) showing that the original skull flaps were used in the reconstruction with titanium mesh and plates. Note that the point where the paper clips (yellow arrows) cross is just beneath the dermal fistula, and there is a titanium mesh plate, not the original skull, at this point.

surgery, unexpected amounts of bone wax and hydroxyapatite (HA) granules were used to fill the spaces, which were removed. However, even after debridement, the local skin flap method failed, and an ulcer reappeared on the local flap.

Another Corrective Surgery

In January 2007, correction of the dermal fistula, the frontal paranasal sinus, and the bone reconstruction was planned and was performed in a single surgical procedure with the inverted and segmented galea-calvarial flap method. The method for harvesting the galea-calvarial flap has been previously described⁵. In brief, the outer table of the calvaria was harvested in pieces without being detached from the galeal flap⁵. During the operation, the skin flap was designed according to the previous incision of the coronal skin. Titanium mesh, plates, and a smaller piece of autobone at the site were completely removed. After large amounts of bone wax and HA granules near the frontal sinus were removed, a damaged roof and poor reconstruction were exposed. The bone wax and HA granules appeared to have been used in the initial surgery performed in 2001 to obstruct the natural draining function through the nasofrontal duct; thus, those materials were completely removed to achieve natural drainage. Cranialization was also performed to improve the working spaces. Damaged frontal sinus mucosa was primarily sutured and secured with gelform fibrin glue. To isolate the mucosal space from the epidural spaces, a monopedicle galeal flap was used. A segmented galea-calvarial flap was used on the reverse

side of this layer (Fig. 2) so that the flap of the galeal part would cover the previous monopedicle galeal flap and be doubly secured for this isolation. The vascularized outer table of the calvaria covered the reverse side of the bone defect (Fig. 3) to match its surface level with the surrounding contour; this was enabled by the segmentation of the calvaria. The dermal fistula was sutured, and the skin was closed.

Postoperative Course

Postoperative 3-dimensional computed tomography showed the coverage of the cranial defect. Follow-up after 7 years showed no recurrence of the dermal sinus or paranasal sinusitis.

Discussion

When the Frontal Sinus Opens during Surgery

Problems of the forehead will develop when the frontal sinus is drained via the nasofrontal duct, which becomes blocked, and collapses from the forehead⁶. Repair of the forehead involves re-drainage of the nasofrontal duct and the reconstruction of both soft tissue and hard bone tissues at the same time. In some cases, a drainage duct is placed from the paranasal space to the nasal space for as long as 2 weeks⁶. In the present case, the downward drainage could be re-secured only when bone wax and HA granules, which had been placed in the frontal sinus, were removed to reopen the nasofrontal duct. Our use of an inverted vascularized calvarial flap was useful for other repairs, such as the repair of an outlining defect of the frontal sinus mucosa to isolate the sinusoidal spaces

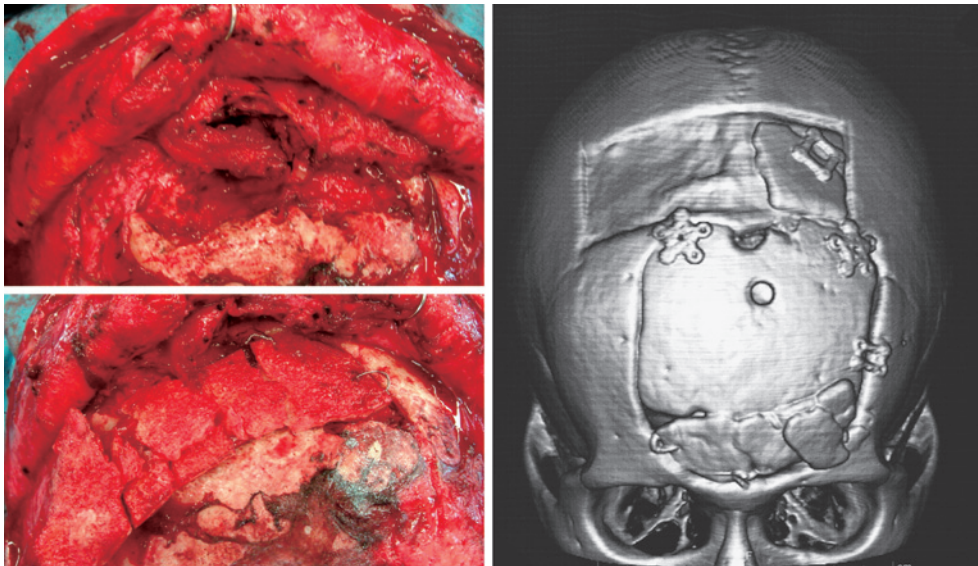


Fig. 2 The frontal sinus is closed primarily with Gelform™ with fibrin glue, and the monopedic- cle galeal flap is isolating the frontal sinus from the epidural spaces (upper left) An inverted and segmented galea-calvarial flap covers onto this monopedic- cle galeal flap to doubly secure the isolation, and cranial reconstruction preserves the blood supply from the galea into the outer table of the calvaria (lower left). Note that the segmentation of the calvarial graft makes cranial reconstruction possible when the flap is reversed. Postoperative 3-dimensional computed tomography shows the proper use of a calvarial graft (right).

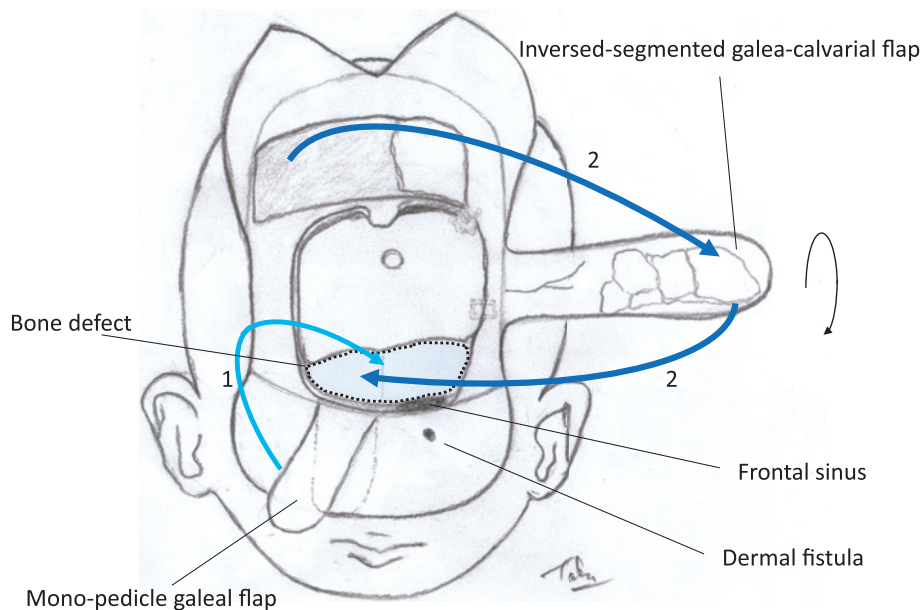


Fig. 3 A schematic diagram of the patient

First, the small bone pieces, titanium mesh, and plates (dotted line) are debrided and removed. The damaged frontal sinus is primarily closed using Gelform fibrin glue (procedure not shown on the scheme). The monopedic- cle galeal flap (1) covers the frontal sinus, and the inverted and segmented galea-calvarial flap (2) is then placed to cover the entire bone defect. Note that the flap is turned around from the parietal to the frontal side and rotated along with the axis of the flap so that a piece of the calvaria, which had been harvested from the right parietal, is grafted at the left frontal side with the piece facing toward the surface.

from the cranial spaces and the forehead.

Vascularized Calvarial Flaps

Vascularized calvarial bone grafts were originally used to reconstruct scarred or irradiated beds or midface hypoplasia defects⁷ and are now widely used for reconstruction after tumors have been resected from the midface⁸ to the skull base^{9,10}. An advantage of vascularized calvarial flaps is that they provide vascularity, which increases the stability of the osseous grafts and blood supply for soft-tissue reconstruction. The use of vascularized calvarial flaps has been examined for cranial reconstruction^{5,11}.

Other techniques for adding vascularity during cranioplasty include the combination of an omental graft¹² or a pericranial on-lay graft, which has recently been reported as a multidisciplinary approach with good results¹².

Inverted Monopedicle Flaps

A monopedicle flap can be used in inverted fashion as long as it is tension-free and watertight¹³, and this flap is often inverted for reconstruction. We refer to this flap as being "inverted," because one side of it differs from the other. Such inverted flaps are used in several different fields, including dental surgery¹³, ophthalmology¹⁴, and penile reconstruction¹⁵.

Frontal Sinus Reconstruction

Dead spaces and the obstruction between the paranasal space and the cranial space or the forehead should be eliminated. Dead spaces can be eliminated by being packed with flaps, through tenting, or through the use of vascular muscle pedicle flaps. When a pedicle flap is used to pack a dead space, it should not be tightly applied because dead spaces can be produced between the cranium and flap. The "tenting method," a technique preferred especially by Japanese neurosurgeons to tack the dura matter to the bone flap with several sutures, is also useful for avoiding free spaces between the dura and the skull. When the pedicle galeal flap is harvested, the frontal muscle is attached to eliminate the dead spaces. Free flaps and free fat have been successfully used in most cases; however, they may not be functioning as well as vascularized grafts and are repeatedly absorbed.

The frontal sinuses are usually isolated with a vascularized flap; however, a free graft, such as the free fascia lata graft, is also an option. A free autograft can be used when there are no dead spaces, bacteria, or foreign bodies. Thus, a free fascia lata graft is not suitable for isolating the frontal sinus.

Limitations

A limitation of our technique is its aesthetic result. Our technique has the goal of achieving the smoothest contour, even though the calvaria is cut into several pieces and applied to the opposite convexity (i.e., concave to a convexity); however, this technique does not fully augment hard tissue. A possible solution to overcome this aesthetic disadvantage is the use of tissue-friendly allografts¹⁶. A further technique must be developed to achieve a better aesthetic result after adding vascularity during the cranioplasty to minimize possible infection and bone absorption.

Conflict of Interest: None.

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