



# Frontal sinus cranialization

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## KEYWORDS

Frontal sinus;  
Fractures;  
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Facial trauma;  
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The management of frontal sinus trauma varies widely based on the extent of injury and the training and preferences of the surgeon. Cranialization is best suited for severe frontal sinus injuries, with comminution of the posterior table bone. The procedure is typically carried out by a multidisciplinary team, including an otolaryngologist and a neurosurgeon.

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The frontal bone is the strongest bone in the facial skeleton.<sup>1</sup> When force sufficient to fracture it is sustained, injuries to other facial structures, the orbit and orbital contents, and the brain are frequently also present.

Depending on the specific anatomic features of a particular injury, a wide variety of management options are appropriate for frontal sinus fractures. These range from simple observation to fairly extensive, combined surgical approaches by the otolaryngologist and neurosurgeon. Frontal sinus cranialization is representative of the latter.

Cranialization evolved to address extensive wounds of the frontal skull. Typically, these injuries involve both the anterior and posterior table bone, often with comminution. The frontonasal outflow tract (a.k.a. frontonasal “duct” or recess) may be compromised. The dura and frequently the frontal lobes of the brain themselves are disrupted.

In the past, complex frontal bone fractures were managed quite differently.<sup>2</sup> All bone fragments were debrided—as devitalized bone within such an open wound was considered a nidus of both early and late infection. The resultant bony defect also allowed for the swelling of the traumatized brain. Watertight closures of both the dura and the overlying skin were then performed.

Cosmetic issues were significant with this approach, due to the loss of forehead projection. Furthermore, a long-term risk of mucocele and mucocele-related infectious complica-

tions might remain for the patient if all the sinus mucosa was not meticulously removed from the wound.

Cranialization addresses these issues. The anterior table is repaired and retained, preserving facial cosmesis. Removal of the posterior table and sinus mucosa eliminates the frontal sinus per se, while providing some additional room for brain edema, as well as a decreased risk of mucocele. The expanded anterior cranial fossa thus created is then permanently separated from the nasal cavity.

## Indications

The primary indication for cranializing the frontal sinus is severe traumatic injury of the frontal sinus, with involvement of both the anterior and the posterior tables. A less common need for this type of procedure might be as closure after some anterior skull base tumor surgeries. Obliteration of the frontal sinus, with complete mucosal removal, plugging of the frontonasal outflow tract, and fat grafting of the entire sinus cavity, is an option in some cases. However, the loss of a substantial portion of the posterior table bone places the survival of a fat graft necessary for obliteration in doubt and makes cranialization more appropriate.<sup>3</sup>

In less severe cases, when the posterior table component is non- or minimally displaced and the frontonasal outflow tract appears intact, consideration may be given to less extensive procedures (ie, open reduction with internal fixation [ORIF] of the anterior table) with close clinical and radiographic follow-up. Should problems later be detected, these sinuses can then be salvaged with frontal sinus drainage procedures; our enhanced abilities to perform the salvage endoscopically are popularizing this management approach.<sup>4</sup>

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The presence of cerebrospinal fluid (CSF) rhinorrhea, the need for neurosurgical intervention, or simply an expectation of inadequate follow-up are all factors that may guide one toward cranialization in otherwise equivocal cases.

## Technique

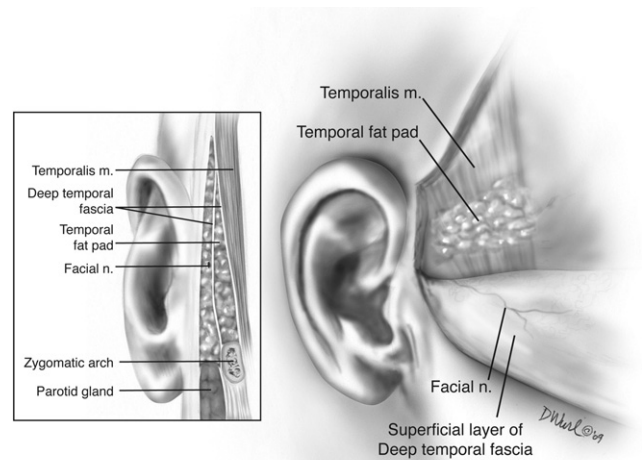
The key operative tasks that constitute frontal sinus cranialization are as follows: (1) obtain wide access to the interior of the frontal sinus; (2) remove all bone of the posterior table; (3) remove completely all frontal sinus mucosa; (4) create a secure barrier between the nose/nasofrontal duct and the frontal sinus/neoanterior cranial fossa; (5) open reduction and fixation of the anterior table of the frontal sinus (with mini-plates, bone grafts, mesh, etc., as indicated; and (6) soft tissue closure.

In essentially all cases, the approach to frontal sinus cranialization is performed via a bicoronal incision. This approach provides wide access to the entire upper facial skeleton, for instance, allowing repair of associated naso-orbito-ethmoid fractures. Furthermore, it allows the harvest of a pericranial flap and split calvarial bone grafts as needed for the repair, while being well camouflaged within the hairline in the vast majority of patients. Other options for access, such as an injury-associated laceration or a “gull-wing” incision, do not allow the same level of visualization, and in the case of the latter, may be cosmetically less favorable.

The bicoronal incision is designed several centimeters behind the patient’s hairline. The injection of local anesthetic with epinephrine, placement of a running locking stitch just beyond the skin edges, and the application of Raney clips may all improve hemostasis. The knife blade is beveled to parallel the hair shafts to prevent postoperative alopecia. The flap is elevated in a subgaleal plane, with pericranium left down to be raised later as needed for reconstructive purposes. Alternatively, the pericranium may be elevated with the skin-galeal flap and separated later.

The final important technical point regards the lateral plane of dissection. At the level of temporal line of fusion, the dissection must be carried deeper, deep to the superficial layer of the deep temporal fascia to avoid transection of the frontal branch of the facial nerve, which travels in this fascia (Figure 1). It is also important not to raise the temporal fat pad as some have suggested to protect the frontal branch. This technique devascularizes the fat pad and can result in significant temporal wasting.

To safely enter the frontal sinus without violating the intracranial space, some method must be used to visualize the borders of the irregularly shaped sinus on the overlying anterior table bone. The traditional method has been an anterior–posterior plain film of the skull (6-foot Caldwell view) cut out, sterilized, and used as a template. A trephination and insertion of a sinus telescope may achieve the same ends via transillumination. In some cases, the bony injury itself may provide the visualization necessary, or at least the access for a telescope. Yet another option is the use of an image-guided surgery system.



**Figure 1** The temporal line of fusion. Below this line, the deep temporal fascia has two layers, with temporal fat pad lying between them. The frontal (temporal) branch of the facial nerve travels superficial to the more superficial layer. If dissection must be carried more inferior than this line, it must be performed deep to the superficial fascial layer, just above the fat pad, to protect the nerve.

In reality, in most cases, these patients are being managed in tandem with the neurosurgical team. They have undergone a frontal craniotomy, which in addition to allowing the brain and dural work to be undertaken, also affords the wide access to the frontal sinus needed for the cranialization.

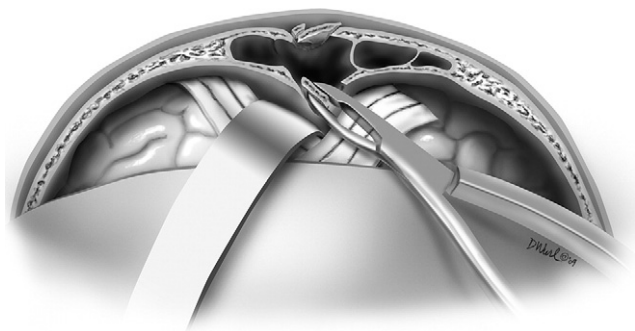
Once access to the posterior table has been achieved, it is removed carefully in pieces with a rongeur (Figure 2). Larger pieces are saved (in moist gauze) for possible use replacing defects in the anterior table, in lieu of separately harvested bone grafts. Small overhangs at the periphery of the sinus should be smoothed completely, using a cutting burr. If a craniotomy has been performed, the portions of the posterior table associated with the craniotomy bone flap can be removed very easily and safely, working on a sterile side table.

The end result of the removal of the posterior table bone is the elimination of the frontal sinus as a distinct space. This space is now encompassed within a new, larger anterior cranial fossa, with anterior table as its anterior limit.

Once the entire posterior table has been removed, all sinus mucosa is taken out. This is done first bluntly, with a hemostat or forceps. Remnant mucosa is then eliminated using a diamond burr under loupe magnification (Figure 3).

Establishing a secure barrier between the neoanterior cranial fossa and the nose is necessary to prevent CSF leak and meningitis, but also to prevent ascending regrowth of the sinonasal mucosa with late mucocele.

After the neurosurgery team has accomplished a watertight dural repair, and the bone and mucosa removal are complete, the most superior aspects of the frontal duct mucosa are elevated from the underlying bone and inverted downwards, toward the nose. Bone is polished with the diamond burr to remove residual mucosa. The superior portions of the ducts are then packed off. A number of substances have been described for this task, including



**Figure 2** The posterior table bone is removed with a rongeur; cottonoids protect the frontal lobes.

bone, fascia, and muscle. The authors' group prefers to use a small amount of muscle.

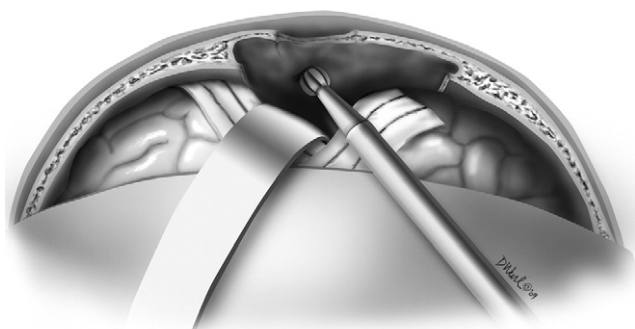
Although the above closure may be considered adequate,<sup>2</sup> an additional measure of security may be achieved with a multilayered closure. Abdominal fat harvested through a small paraumbilical incision is filled in around the dural closure, occupying intracranial dead space. Next, the pericranial flap is interposed between the fat graft and the nasal vault (Figure 4).

Repair of the anterior table is essential for both structural and cosmetic concerns. As in the rest of the sinus, all mucosa is removed from bone fragments prior to repair. Soaking of the fragments in betadine solution prior to repair is also advocated.<sup>2</sup> Anatomic reduction is carried out with fixation using appropriate hardware, typically lower profile miniplates. For severely comminuted fractures or those with missing bone, titanium mesh is a useful adjunct,<sup>5</sup> as are larger bone fragments harvested from the posterior table; split calvarial bone grafts may also be useful.

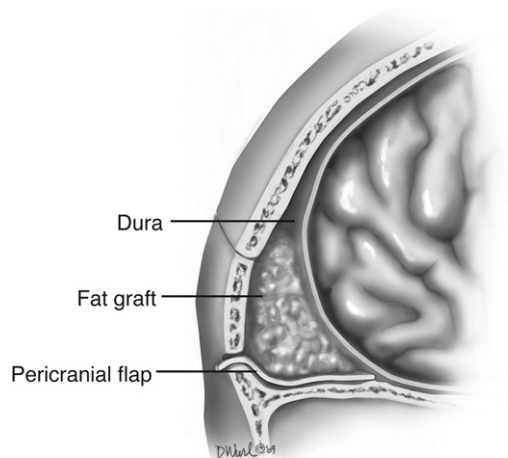
Closure of the coronal incision is performed in layers with interrupted 3-0 vicryl stitches for the galea and deep dermis, and staples for the skin within the hairline. The skin outside the hairline is closed with interrupted 4-0 vicryl stitches. Suction drains are generally avoided due to the immature dural closure. A neurosurgical head wrap is then applied.

## Complications

Some complications of frontal sinus cranialization clearly relate to surgical technique. The frontal branch of the facial nerve



**Figure 3** Mucosa is removed from the anterior table using a diamond burr drill under loupe magnification.



**Figure 4** A sagittal view of layered closure employed in cranialization.

is vulnerable to injury during elevation of the coronal skin flap. The result is paralysis of the ipsilateral forehead. This complication can be avoided by elevating the lateral aspects of the coronal flap in the proper plane, as described above. Likewise, too much disruption of the temporal fat pad during the lateral dissection can cause noticeable late hollowing.

A noticeable or widened scar from the coronal incision may develop. Consideration should be given to better camouflaged designs for the incision employing geometrical, broken-line principles.<sup>6</sup>

Other complications connect more to the nature of the injury itself. CSF leak/rhinorrhea, with or without infectious consequences, may develop despite the fact that a watertight closure of the dura is performed in conjunction with cranialization. Management typically involves revision surgery, although nasal packing, bedrest, and CSF decompression via lumbar drain may be helpful adjuncts. More recently, endoscopic endonasal management of CSF leak has become very useful, but the nature and location of posterior table frontal sinus CSF leaks makes this approach only useful in very select cases.

Appropriate management of meningitis relies on early recognition of signs, such as mental status changes, fever, and nuchal rigidity. This can be challenging in this patient population, where head injury and mental impairment are the norm. When detected, broad-spectrum antibiotics with CSF penetration should be employed empirically, with adjustments to the regimen based on subsequent cultures.

A noticeable contour defect is always a possibility in the management of frontal sinus trauma, particularly in the subset of patients who are cranialized (ie, those with significant displacement and comminution). Meticulous reduction and fixation of all bone fragments and the appropriate use of bone grafts, titanium mesh, and bone cements are critically important for avoiding this complication. A secondary cranioplasty will often address this issue very nicely.

Severe, chronic, frontal pain is an unusual but well-documented<sup>7,8</sup> phenomenon after frontal sinus injury, for which no clear-cut remedy (or method of prevention) has been described.

Finally, the formation of a frontal mucocele, which may progress to mucopyocele, frontal bone osteomyelitis, and brain abscess, is a well-known complication of frontal sinus fractures. The incidence of mucocele is difficult to estimate due to problems with follow-up in the trauma population, continued evolution in the management of these fractures, and the fact that mucoceles may occur very late, years to even a decade or more after the original injury and surgery.

Most series report incidences of complications in frontal sinus fracture patients who underwent a variety of surgical treatments. Wallis and Donald<sup>7</sup> report a 6% incidence of mucocele, all developing within several months after initial treatment. Interestingly, none of the 30 patients whom they cranialized developed this complication. Several other large series<sup>4,8</sup> of frontal sinus fracture patients make no specific mention of mucocele but describe several patients developing late "sinusitis" and "frontal bone osteomyelitis," which likely are a consequence of mucoceles.

## Discussion

For appropriately selected patients with extensive frontal injuries, cranialization is a procedure that provides an excellent margin of long-term safety and a satisfactory esthetic

outcome. Individual surgeons will continue to differ at times as to the appropriate management of a particular frontal injury. Nevertheless, for the most severe of these, cranialization continues to be the definitive treatment.

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