

**TITLE: Frontal Sinus Fractures**

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Frontal sinus fractures occur in 5-12 % of patients that suffer maxillofacial injuries. They occur as a result of high velocity impacts and are most often found in males in their late twenties. The advent of mandatory seat belt laws and airbags in automobiles has drastically reduced their incidence. <sup>(1, 6, 11, 15)</sup>

Development of the frontal sinus begins between the ages of two and four. Anterior ethmoid cells expand into the frontal bone and are radiographically evident by the ages of five to eight. Between the ages of twelve and eighteen, the sinuses reach full adult size. Fifteen percent of people have only one sinus and four percent of people will not develop a frontal sinus. The anterior table thickness ranges from 2 to 12 mm and the posterior table thickness ranges from 0.1 to 4.8 mm. The thickness of the anterior table and its stable position make it extremely difficult to fracture. It takes 800 to 1600 ft lbs of torque to fracture the anterior table. <sup>(1, 6, 11, 15)</sup>

Because of the high amount of energy needed to fracture the frontal sinus and its proximity to the cranial vault, other injuries occur in at least one third of all patients. Up to 72% of patients lose consciousness at the time of injury and about one fifth of patients are obtunded at the scene and may require intubation. About one quarter of patients have associated neurologic injuries, including; pneumocephalus (26%), cerebral contusion (18%), dural tear (14%), cerebrospinal fluid (CSF) leakage (11%) and epidural hematoma (8%). <sup>(1)</sup>

The most common mechanism for fracture are motor vehicle accidents, which account for 52% of fractures. Assault (26%), recreational accidents (9%) and industrial accidents (5%) are the other most common causes. <sup>(1)</sup> A review of sports related injuries in Europe found that soccer and rugby account for 40% of fractures, 34% of fractures were related to more extreme sports and 6% were related to martial arts. <sup>(2)</sup>

Fractures are typically grouped into involvement of the anterior table, posterior table and the nasofrontal duct. Data from three recent reviews are collected in Table 1. The combination of anterior and posterior table fractures accounts for about 70% of fractures. Isolated anterior table fractures occur about 30% of the time and isolated posterior table fractures occur rarely

(3%). Not all authors explicitly classified nasofrontal duct fractures because they are difficult to diagnose both preoperatively and intraoperatively. <sup>(1, 6, 15)</sup>

		Anterior	Posterior	Ant/Post	Frontal recess	Total
Wallis et al	1974-1986	13 (18%)	2 (3%)	55 (79%)	2	70
Strong et al	1987-2002	35 (28%)	4 (3%)	88 (69%)	3	127
Gossman et al	1990-2003	48 (50%)	0	48 (50%)	n/a	96
Chen et al	1994-2002	22 (28%)	0	56 (72%)	n/a	78

Table 1: Fracture distribution. (1, 6, 15)

Seventy five percent of patients will have other maxillofacial fractures. Maxillary, orbital and zygomatic fractures are the most common. All pediatric patients reviewed were found to have orbital fractures. (1, 15, 16)

Complications from frontal sinus fractures occur in about 8% of patients. Major complications are meningitis and mucocele formation, which occur in about 5% of patients. The incidence of meningitis is directly linked to the rate of persistent postoperative CSF leaks. Strong et al found that 5% of their patients had persistent CSF rhinorrhea and about 3% of their patients developed meningitis. Friedman et al have found that post traumatic CSF rhinorrhea may be underreported initially. They also found that the incidence of meningitis in patients with persistent CSF leaks (> 24 hours) decreased by 50% when they were placed on prophylactic antibiotics. Mucocele development occurs rarely after fractures (1-2%) but may occur more than a decade after reparative surgery. Minor complications include perioperative wound infections, frontal paresthesias, frontal branch paresis/paralysis, frontal bone contour irregularities, and diplopia. <sup>(1, 3, 6)</sup>

Fracture management ranges from observation to frontal sinus cranialization. Intervention should be weighed in relation to the patient's overall status. Many of these patients may be in critical condition and management of the fractures is put off until they are more stable. The primary goal of intervention is to prevent further damage to the brain by separating the cranial vault from the nasal and sinus cavities. Preservation of normal sinus function and correction of cosmetic deformity are secondary goals. <sup>(11)</sup>

Anterior table fractures may occur as isolated injuries. Non displaced anterior table fractures may be observed. Displaced fractures are usually reduced via open approaches (coronal, mid-brow). Authors have described using endoscopic browlift techniques to approach and reduce fractures with miniplates as well. A case report of attempted closed reductions of anterior table fractures ended up needing revision surgery to retrieve the tip of the reduction probe from the sinus. Severely comminuted fractures can be reduced with multiple plates but titanium mesh has been shown to give good cosmetic outcomes. Special care should be taken with comminuted fractures to ensure that no mucosa is trapped between the bony fragments. <sup>(8, 9, 10, 11)</sup>

Posterior table fractures almost always occur in combination with anterior table fractures. The risk for CSF leak and resultant meningitis is increased with posterior table involvement. Management of these injuries revolves around separating the intracranial cavity from the

nasosinal cavities. If a CSF leak is present and does not spontaneously resolve then exploration of the sinus is recommended. Some authors advocate that posterior table fractures that are displaced more than one table width should be explored and obliterated or cranialized. Other authors have shown that the designation of the one table width cut off does not predict any adverse outcomes but that persistent CSF leak should be the determining factor for cranialization. Exploration should be combined with neurosurgery in order to address any potential dural tears. Cranialization procedures should be considered for all severely comminuted posterior table fractures. Pedicled pericranial flaps have been used to aid in cranialization as well as to obliterate the sinus. <sup>(11, 12, 13, 14, 15)</sup>

Suspected injury to the nasofrontal duct should always be evaluated in these patients. Review of CT scans for anterior ethmoid fractures or obvious fracture lines through the duct are difficult to assess and do not correlate well with intraoperative assessments. Intraoperative assessment of nasofrontal duct patency is not easily performed either due to post injury mucosal edema in some patients. Because of the potential long term complications of mucocele and chronic sinusitis resulting from poor outflow, some authors advocate more aggressive surgical management. The goal of oblitative and cranialization procedures is to remove any frontal sinus mucosa and then destroy the outflow tract into the nasal cavity. The mucosa in the ducts is everted into the nasal cavity and the superior portions are plugged with some sort of tissue (fascia, muscle, bone chips) and usually sealed with bioadhesive (fibrin glue or tisseal). Other authors advocate more expectant management of the frontal ducts, especially in patients without any evidence of injury. Because follow up for trauma patients is typically poor and follow up for patients without active symptoms is poor; patient selection for symptom observation is very important.

Frontal sinus obliteration dates back to the 1950's. Dr. Bergara postulated that transplanted fat would be able to survive in the frontal sinus cavity and that non-viable portions would fibrose and continue to obliterate the space. Goodale and Montgomery popularized the procedure after documenting no major symptom recurrences after five year follow up. Since the 1960's, obliteration has been the standard of care for difficult frontal sinus disease. Hardy and Montgomery followed 250 patients for 8 years and reported an overall complication rate of 18%, mainly from post op infections from the donor and implant site. 4% of their patients had revision surgery.

Weber's principles for successful obliteration surgery are as follows:

1. Meticulous removal of all visible mucosa
2. Removal of the inner cortex
3. Cutting burr for thick bone and a diamond burr for the dura and orbital roof–periorbita
4. Results do not depend on the choice of microscope or Loupe magnification
5. Permanent occlusion of the nasofrontal duct
6. Material that forms a fibrous barrier between the obliterated sinus and the nasal cavity.
7. Prevents the implanted material from sliding downward and impairs the ingrowth of nasal mucosa.

Numerous materials have been used to obliterate the frontal sinus. (Adipose tissue, pericranium, hydroxyapatite, temporalis fascia, bone chips, Gelfoam, and lyophilized cartilage.) Fat is the most commonly used material. Weber and Draf have shown that post op outcomes are not influenced by the degree of surviving fat in obliterated cavities. In their review of 59 patients, they found that less than 20% of implanted fat survives in 53% of patients. Only 18% of patients have more than 60% of implant survive post operatively. They estimate the half life of implanted fat is 15.4 months. Post operative imaging (MRI) for surveillance of mucoceles is recommended for all obliteration patients. Interpreting the images can be challenging because of the high variability of the implanted adipose tissue and mucoceles on MRI. Mucoceles have been reported up to 10 or 20 years after surgery, so long term follow up is recommended for all patients. Weber's series of 52 patients had a post op mucocele rate of about 10%.

Pericranial flap obliteration has been described by multiple authors as an alternative to adipose implantation. Use of this flap eliminates a second wound and it is a vascular implant into the cavity. The flap can be anteriorly (supratrochlear) or laterally (superficial temporal) based and is able to obliterate large cavities. The flap is placed into the cavity under the osteoplastic flap after a portion has been drilled away in order to preserve the pedicled blood supply. The post op infection rates for pericranial flaps are lower than fat obliteration because of the established vascular supply.

Management of these injuries can be difficult. By examining each injury in terms of the individual injuries to the anterior table, posterior table, frontal duct and intracranial injuries, the proper surgical plan can be chosen. There is no consensus on which procedures to perform for these injuries. Gossman et al observed 47%, obliterated or cranialized 19% and performed and ORIF on 30% of their patients. Chen et al observed 7%, performed an ORIF with sinus preservation in 51% and obliterated or cranialized 41% of their patients. Strong et al performed an ORIF on 6% and obliterated or cranialized 92% of their patients. When comparing these three recent reviews, there was no obvious difference in overall complication rates despite the obvious differences in surgical management. No matter which course of action is taken for the patient, consistent follow up is needed to detect any long term sequelae.

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