

Immediate Reconstruction of Frontal Sinus Fractures: Review of 26 Cases

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Purpose: The purpose of this study was to evaluate complications occurring after immediate reconstruction of severe frontal sinus fractures, including cases where the fracture was not limited to the anterior wall and also involved the posterior wall and/or sinus floor.

Patients and Methods: The records of twenty-six patients presently undergoing follow-up for frontal sinus fracture reconstruction were reviewed. Information regarding demographics, fracture characteristics and causes, associated facial fractures, use of grafts or implants, type of fixation used, nasofrontal duct management, use of antibiotics, and complications were noted. Patients were asked to return for clinical and radiographic follow-up to access late complications.

Results: The average age of patients with frontal fractures was 29.1 years and 92.3% were male. Mean follow-up was 3.6 years. The most common causes of fracture were motor vehicle accidents and physical aggression. All patients presented with comminuted and dislocated anterior wall fractures, 34.6% presented with posterior wall fractures, and 46% had sinus floor fractures. Complications occurred in 7 patients (26.92%) and included pneumocephalus, frontal cutaneous fistula, frontal bone irregularity, and sinusitis.

Conclusions: Frontal sinus reconstruction is a good procedure for immediate fracture treatment if there is not excessive comminution, dislocation, or instability of the posterior wall and if the frontonasal duct area is intact or can be repaired. Most complications result from incorrect indication for reconstruction.

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Fractures involving the frontal sinus may cause complications related to the sinus and intracranial, orbital, or nasal structures. Their incidence varies from 2% to 15% of all facial fractures. Also those are the cranial fractures most frequently associated with facial fractures.¹⁻³ Mainly due to the possibility of late complications and sequelae, the best treatment modality for frontal sinus fractures is still controversial.

The goals of treatment, on the other hand, are well established: isolation of intracranial contents, correction of cerebral spinal fluid leakage, prevention of infection and sequelae, restoration of functional integrity of involved structures whenever possible, and restoration of frontal contour and aesthetics.^{4,5} In general, anterior wall fractures are reconstructed, whereas posterior wall fractures and lesions to the drainage system are treated via obliteration or craniolization of the sinus.⁶⁻¹¹ However, primary immediate reconstruction of the frontal bone and sinus is becoming much more widely accepted.^{3,12} This article evaluates patients with severe frontal sinus injuries treated by immediate reconstruction, even in the presence of posterior wall or sinus floor fractures.

Patients and Methods

Twenty-six patients from the Oral and Maxillofacial Surgery Division of the Hospital Santa Casa de Araraquara, Sao Paulo, Brazil, who had immediate frontal sinus fracture reconstruction in the period from 1992 to 2002, were retrospectively reviewed, considering

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Table 1. CAUSE OF FRACTURE

Fracture Cause	n (%)
Motor vehicle accident	16 (61.53)
Aggression	4 (15.38)
Explosion	2 (7.69)
Sports	3 (11.53)
Animal trauma	1 (3.84)

the longest available follow-up of a minimum of 6 months. Subjects were included if records provided enough information about their perioperative care pertinent to the investigation. All patients were operated on by the same surgical team within 72 hours of injury, and reconstruction of the sinus was performed whenever feasible independent of the presence of fractures of the sinus floor and/or posterior wall, as long as those were not severely dislocated or too unstable. Bicoronal flaps were the preferred access in all cases with one exception where an extensive laceration allowed access to the frontal sinus. Before reconstruction, the sinus mucosa was thoroughly removed.

Fractures of the anterior wall were reconstructed and rigidly fixed with miniplates and screws, with the exception of 2 cases. Immediate split cranial autogenous bone grafts were used when comminution was excessive or bone was lost; a split rib autogenous graft was used in one case and another one received a Medpor implant (Porex Surgical Inc, Newnan, GA). Fractures of the posterior wall were left alone or carefully repositioned. Sinus floor fractures received autogenous cranial bone grafts when needed to reconstruct the orbital roof, with the exception of one case where Medpor implants were used to reconstruct the orbital walls and another where the orbital roof was repaired with a maxillary sinus anterior wall graft.

When the drainage system was clearly intact, the mucosa around the nasofrontal duct orifices was preserved and no attempt was made to cannulate the ducts. When in doubt of drainage patency, methylene blue dye was used to test duct permeability with care to keep the dye within the area of drainage and thoroughly rinsing it afterwards. When damage to the drainage system was perceived in the preoperative imaging examination or during surgery, the nasofrontal ducts were cannulated with suitable-sized silicone tubing or an intravenous catheter that was maintained within the sinus and extruded by the nostrils, where it was fixated with a 5-0 nylon suture (Ethicon; Johnson & Johnson, São José dos Campos, Sao Paulo, Brazil) and kept for 15 to 21 days. All patients received preoperative and postoperative intravenous antibiotics. Although computed tomography (CT)

Table 2. CHARACTER OF FRACTURE

Fracture Character	n (%)
Anterior wall (comminuted/dislocated)	26 (100)
Posterior wall (linear)	3 (11.53)
Posterior wall (dislocated)	6 (23.07)
Sinus floor	12 (46.15)

scans were available for preoperative evaluation, postoperative CT scans were used in this population only for those who presented complications, due to economic reasons. Postoperative evaluation was done by clinical assessment and radiographs (Water's view and lateral cephalogram). Demographic data, fracture characteristics and causes, associated facial fractures, use of grafts or implants, type of fixation used, nasofrontal duct management, use of antibiotics, and complications were noted.

Results

In the studied population, 92.3% of the patients were male and mean age at the time of fracture was 29.1 years (11 to 66 years). Mean follow-up was 3.6 years (6 months to 9.5 years). The main causes for the injury were motor vehicle accidents and physical aggression, as shown in Table 1. All patients had anterior wall fractures, 34.6% presented with posterior wall fractures, and 46.15% had sinus floor fractures (Table 2).

Frontal sinus fractures were frequently associated with panfacial fractures in this population. Table 3 shows the associated facial fractures. Twenty-four patients (92.3%) had fixation of the anterior sinus wall with miniplates and screws; in 1 case, wire fixation was used, and 1 patient received only elevation of the anterior wall without fixation. Nine patients (34.61%) needed grafts or implants to help to reconstruct the anterior wall of the sinus (Table 4). Ten patients (38.46%) received reconstruction of the orbital roof (Table 5). Seven patients (26.92%) needed cannulation of the frontal ducts.

Table 3. ASSOCIATED FACIAL FRACTURES

Associated Fracture	n (%)
Panfacial	8 (30.76)
Orbital roof (isolated)	5 (19.23)
NOE (isolated)	2 (7.69)
Zigomatic complex (isolated)	1 (3.84)
Mandible (isolated)	1 (3.84)
None	9 (34.61)

Abbreviation: NOE, naso-orbital-ethmoid.

Table 4. MATERIAL USED IN ANTERIOR WALL RECONSTRUCTION

Material	n (%)
Split cranial graft	7 (26.92)
Medpor	1 (3.84)
Split rib graft	1 (3.84)

Seven patients (26.92%) presented with complications, which were related to infections in 5 cases (19.23%) (Table 6). Table 7 shows the length of post-operative follow-up when those complications were diagnosed.

DISCUSSION

Patients with frontal sinus fractures presented with the same preferential gender, age, and cause of injury as any facial trauma patients. In the studied population, there are also high levels of substance abuse, mainly alcohol and sometimes illegal drugs, in our setting. Also, high speed driving and poor compliance with the use of seat belts are not uncommon. Association with complex facial fractures is frequent, mainly in motor vehicle accidents, but also as a result of aggression.

The best treatment of frontal sinus fractures is controversial. This is due to the fact that sequelae may take many years to occur and involve intracranial structures with severe consequences. However, it should be pointed out that most frontal sinusitis and mucocoeles occurring in the general population are not associated with trauma.^{13,14} Also, it is not easy to be sure that a frontal mucocoele or sinusitis occurring after a follow-up of many years is indeed due to a previous traumatic event. In general, whatever technique is used, it is difficult, if not impossible, to follow large series of patients over 20 years, to ascertain the absence of complications. Indeed, it is not even clear how long that follow-up should be.

Surgery should create a "safe" sinus and recover sinus function if indicated or eliminate the sinus by obliteration or cranialization, as well as recover aesthetics.^{5,15,16} All techniques imply complete removal of the sinus mucosa. In limited lesions, removal only of the injured and devitalized tissue is sufficient, because the remaining healthy mucosa will heal as

Table 5. MATERIAL USED IN ORBITAL ROOF RECONSTRUCTION

Material	n (%)
Split cranial grafts	8 (30.76)
Medpor	1 (3.84)
Maxillary sinus anterior wall graft	1 (3.84)

Table 6. CHARACTER OF COMPLICATIONS IN 7 PATIENTS

Complication	n (%)
Clinical sinusitis	4 (15.38)
Radiographic sinusitis	5 (19.23)
Frontal fistula	1 (3.84)
Pneumoencephalus	1 (3.84)
Frontal bone irregularity	3 (11.53)

long as the sinus was previously healthy. History of recurrent sinusitis, extensive mucosal lesion, or damage to the frontonasal ducts warrants complete removal, even using a bur to eliminate invaginated mucosa.^{16,17}

When the frontal duct is injured, most authors prefer to treat the sinus by obliteration or cranialization, the latter especially when there are comminution of the posterior wall, dural tears, and persistent cerebrospinal fluid leak.^{4,5,7,9-12,16,17} Recanalizing the duct and usually maintaining a tube catheter for 2 weeks is a viable alternative.^{11,12} This was done in 7 of the studied patients who had very severe fractures, and the complications that occurred in 3 of those patients were not related to sinus drainage. This is a good technique provided that the sinus floor does not present such distortion or loss of substance that drainage is beyond repair.

The complications observed in this group of patients are those usually described in the literature. The rate of 26.92% of the patients presenting with complications is higher than that described in the literature, which is around 10% to 14%^{11,17} in series discussing groups of patients who were treated by several different techniques. That may be due to differences in population, character of fractures, method of treatment, and certainly by stretching the indication for the use of reconstruction in some of the studied cases.

Two patients with extremely comminuted anterior wall fractures presented frontal bone irregularity in the long-term follow-up. Management of comminuted anterior wall fractures often represents a problem, especially when bone is missing.¹⁸ Adequate repair is only accomplished by means of direct reduction and

Table 7. TIMING OF PRESENTATION OF COMPLICATIONS

Complication	Time (mo)
Sinusitis	30 to 66
Frontal cutaneous fistula	66
Pneumoencephalus	0.5
Frontal bone irregularity	12 to 18

fixation and it is not necessary to preserve periosteal attachments.¹⁹ We believe that one exception to that rule is selected cases presenting a very large sinus with great comminution. This setting may result in bone resorption, fragment malpositioning, and future irregularity. In some of these cases, in extreme situations, we prefer to elevate the anterior wall fragments with the periosteum, preserving periosteal attachments. Then a bone graft, preferably a split rib, can be used to make struts for support over which the fragments attached to the periosteum can be repositioned, creating a smooth contour and preventing resorption and irregularity. In another situation, when there is loss of bone, split cranial grafts are an excellent choice to reconstruct the anterior wall. In one of the cases, a Medpor implant was used to repair a large defect without complications.

Decision as to how a posterior table fracture should be treated can be made by analysis of CT scans, if there is extensive comminution and/or displacement. Otherwise a decision can be made by direct visualization when surgically treating the anterior table. Options are observation, sinus reconstruction, obliteration, or cranialization. Gross comminution, displacement, and mobility preclude reconstruction and the choice would be to obliterate or cranialize the sinus, depending on the presence or not of damage to intracranial structures, cerebrospinal fluid leak, and need for neurologic intracranial intervention. In one of our patients with a dislocated and unstable posterior wall, in whom neurosurgery opted not to perform intracranial surgery and who we ended up treating by reconstruction, instead of obliteration, a large pneumoencephalus developed after 2 weeks and demanded neurosurgical treatment with cranialization of the sinus. Main complaints of this patient at the time of diagnosis were mild to moderate headache, apathy, and somnolence.

The most common early complication is infection, which may involve only the sinus cavity or spread to the soft tissues of the forehead, bone marrow, or intracranial cavity. This will take a few days to occur and may result in soft tissue abscess, osteomyelitis, epidural abscess, subdural abscess, meningitis, or brain abscess.²⁰ However, infections may take longer to appear, usually within 3 weeks of the initial treatment.¹⁷ In the studied population, sinus infectious complications were observed in 5 patients (19.23%). The time of diagnosis of infection varied from 8 to 66 months, with an average of 30.16 months. In one of our patients, who had fractures of both posterior and anterior walls and also sinus floor, sinusitis was only observed after more than 5 years after initial treatment. This was a very severe fracture that in retrospect would be best treated by sinus obliteration with cancellous bone.

One patient presented with radiographic signs of sinus involvement, probably fibrosis, without clinical signs and symptoms and is presently under close observation. Another had frontal sinusitis previous to the fracture, which recurred postoperatively. One of the subjects who developed sinusitis had sustained an explosion wound with sinus penetration by debris. A child who was 11 years old at the time of injury developed sinusitis with frontal soft tissue involvement 30 months after his accident. At the time of surgery for treatment of the infection and sinus obliteration with cancellous bone, it was curiously observed that the nasal frontal ducts had spontaneously obliterated since the initial treatment, impairing sinus drainage. One patient with a severe fracture involving anterior wall, posterior wall, and sinus floor developed a viral meningitis 8 months after treatment and was diagnosed as seropositive for human immunodeficiency virus infection. This was not considered to be related to sinus reconstruction. The patient was treated clinically at an infectious diseases hospital and presented no complications after 5.4 years of follow-up.

It is important to observe that reconstruction of the sinus does not preclude further surgery in case of failure. In fact, it may create better conditions for future treatment, especially if a severe complex facial fracture is associated and if the chosen secondary procedure will be sinus obliteration. As previously noted, early initial treatment is important and when the posterior wall is substantially intact it is better to re-establish patency of the nasofrontal duct with a drainage tube.²¹ Previous sinusitis and early age may contribute to failure. However, the main reason for complications in this population was exceeding the indication for sinus reconstruction. Postoperative CT is advisable even when the patient is asymptomatic. Early complications are unusual and the need for very long-term follow-up is warranted. Frontal sinus reconstruction with or without cannulation of the nasofrontal ducts, as needed, is a good technique, provided that the posterior wall is not excessively comminuted, dislocated, or grossly unstable and that the injured nasofrontal duct area is not beyond repair. Most significant complications occur due to incorrect indication for reconstruction.

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