

## ORIGINAL RESEARCH

# Frontal sinus fractures: A 28-year retrospective review

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**OBJECTIVES:** To analyze 202 consecutive frontal sinus fracture (FSF) patients treated between 1974 and 2002 at the University of California, Davis.

**METHODS:** A retrospective chart review was performed, including all patients with frontal sinus fractures from 1987 to 2002. This and 72 previously reported patients (1974-1986) were analyzed, comparing age, gender, fracture type, associated fractures, procedure type, and complications.

**RESULTS:** Frontal sinus fractures resulting from motor vehicle accidents (MVAs) decreased from 71% to 52% ( $P < 0.05$ ). Fractures from assaults increased from 9% to 21% ( $P < 0.05$ ). The incidence of “through and through” fractures decreased from 40% to 11% ( $P < 0.05$ ). Whereas combined anterior/posterior table fractures increased from 36% to 57% ( $P < 0.05$ ).

**CONCLUSION:** The etiology and severity of FSF has changed from 1974 to 2002. This is reflected in a reduced number of fractures resulting from MVAs as well as a reduced severity of injury. The most likely explanation is the use of safety belts and airbags.

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The frontal sinus is protected by thick cortical bone and is more resistant to fracture than any other facial bone.<sup>1</sup> Consequently, frontal sinus fractures are usually the result of high-velocity impacts such as motor vehicle collisions, assaults, industrial accidents, and sports injuries. They are often associated with other facial fractures as well as intracranial injuries. Surgical management can be complex and controversial.<sup>2-4</sup> Long-term sequelae of frontal sinus fractures include chronic sinusitis, mucocele, and mucopyocele. We present our experience with 130 patients treated at UC

Davis from 1987 to 2002 and compare these data with 72 previously reported patients between 1974 and 1986.<sup>5</sup>

## METHODS

After institutional review board approval, a retrospective chart review was performed. It included all patients who presented to the University of California, Davis Medical Center with frontal sinus fractures between 1987 and 2002. One hundred thirty patients were identified. The recorded parameters included age, gender, loss of consciousness, mechanism of injury, presenting symptoms, physical examination, fracture type, associated facial fractures (radiologic diagnosis), intracranial injury, mortality, type of surgical repair, and minor and major complications. All statistical analysis was performed with a 2-tailed Fisher exact test.

## RESULTS

### Demographics

The average age was 30 years (range 8-79 years) (Table 1). Eighty-nine percent of patients were male. The most common fracture etiologies included motor vehicle accidents (52%), assaults (26%), recreational accidents (9%), and industrial accidents (5%). The average follow-up was six months (range, 0-69 months). The incidence of frontal sinus fractures as a result of motor vehicle accidents fell from 71% in group 1 (1974-1986) to 52% in group 2 (1987-2002) ( $P < 0.05$ ). The number of frontal sinus fractures resulting

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**Table 1**  
Demographics of frontal sinus fractures

	Wallis et al (1974-1986)	Current study (1987-2002)	<i>P</i> value
Average age (range)	32 y (15-76)	30 y (8-79)	
Gender			
(% male:% female)	84:16	89:11	
Motor vehicle accident (%)	51 (71)	68 (52)	0.01
Assault (%)	8 (11)	34 (26)	0.01
Industrial accident (%)	5 (7)	7 (5)	0.8
Recreational accident (%)	4 (6)	12 (9)	0.4
Gunshot wound, self-inflicted (%)	3 (4)	3 (2)	0.6
Other (%)	1 (2)	6 (6)	0.4

from personal assaults increased from 11% in group 1 to 26% in group 2 ( $P < 0.05$ ).

### Clinical Examination

Seventy-two percent of patients had loss of consciousness at the time of injury. Twenty-one percent of patients were obtunded or intubated on arrival to the hospital. Fifteen percent of patients complained of visual problems, including diplopia, blurred vision, or decreased acuity. Seventy-nine percent of patients had lacerations of the skin overlying the frontal sinus. The remainder had superficial abrasions and/or frontal swelling. Thirty percent were noted to have palpable step offs or bone fragments within the laceration.

### Fracture Type

Fifty-seven percent of fractures involved the anterior and posterior tables; 27% were isolated to the anterior table (Table 2). Eleven percent were "through and through" injuries with frank violation of the anterior cranial fossa. Three percent were isolated posterior table fractures, and 2% had an isolated frontal recess injury. Comparing groups one and two, "through and through" fractures decreased from 40% to 11% ( $P < 0.0001$ ), and anterior/posterior table fractures increased from 36% to 57% ( $P < 0.05$ ).

### Associated Fractures

One hundred thirteen patients (87%) had one or more associated facial fractures (Tables 3 and 4). Of those, 46 had 2 fractures, 40 had 1 fracture, and 27 had 3 to 7 fractures. The most common associated fracture was the maxilla (29%), followed by the naso-orbito-ethmoid region (22%), nasal bones (12%), zygoma (11%), skull base (11%), mandible (10%), and cranium (5%). Patients with no other fractures decreased from 31% in group one to 13% in group two ( $P < 0.05$ ), and patients with 2 associated facial fractures increased from 17% in group one to 35% in group two ( $P < 0.05$ ).

**Table 2**  
Types of frontal sinus fractures

Fracture type	Wallis et al (1974-1986)	Current study (1987-2002)	<i>P</i> value
"Through-and-through," skin to anterior cranial fossa (%)	29 (40)	14 (11)	<0.0001
Anterior and posterior tables (%)	26 (36)	74 (57)	0.005
Anterior table only (%)	13 (18)	35 (27)	0.17
Posterior table only (%)	2 (3)	4 (3)	1.0
Frontal recess only (%)	2 (3)	3 (2)	1.0

### Associated Soft-Tissue Injuries

The most common intracranial findings included pneumocephalus (26%), cerebral contusion (18%), dural tear (14%), cerebrospinal fluid (CSF) leak (11%), and epidural hematoma (8%) (Table 5). Six patients (5%) were noted to have persistent CSF leaks post-operatively. Five of these stopped spontaneously, and 1 required reoperation to stop the leak. Three patients (2%) died in the hospital as a direct result of the head trauma. The incidence of CSF leak on presentation dropped from 31% in group 1 to 11% in group 2 ( $P < 0.05$ ), and the incidence of brain visible in the wound on presentation dropped from 13% in group one to 3% in group two ( $P < 0.05$ ).

### Surgical Repair

The surgical approach used most frequently was a coronal incision (84%), followed by extension of a laceration (14%), a brow incision (1%), and a lynch incision (1%) (Tables 6 and 7). The majority of patients underwent frontal sinus obliteration with abdominal fat (71%). Twenty-one percent underwent cranialization. Six percent had simple open reduction and internal fixation of the anterior table, and 2% had surgical exploration without repair. The use of

**Table 3**  
Other maxillofacial fractures: number per patient

Number of fractures	Wallis et al (1974-1986)	Current study (1987-2002)	<i>P</i> value
None (%)	22 (31)	17 (13)	0.004
One (%)	27 (37)	40 (31)	0.35
Two (%)	12 (17)	46 (35)	0.006
Three to seven (%)	9 (12)	27 (21)	0.17
Unknown (%)	2 (3)	0	0.13

**Table 4**  
Other maxillofacial fractures: type

Type of fracture	Wallis et al (1974-1986)	Current study (1987-2002)	P value
Maxilla	27 (32%)	52 (29%)	0.76
Zygoma	13 (16%)	19 (11%)	0.55
Naso-orbito-ethmoid	10 (12%)	40 (22%)	0.01
Nasal	8 (10%)	22 (12%)	0.30
Skull vault	8 (10%)	9 (5%)	0.30
Skull base	8 (10%)	19 (11%)	0.53
Mandible	8 (10%)	17 (10%)	0.8
Total fractures	82 (100%)	178 (100%)	

a coronal incision increased from 48% in group 1 to 84% in group two ( $P < 0.05$ ). Access through extension of an existing laceration decreased from 34% in group one to 14% in group two ( $P < 0.05$ ). Brow incisions decreased from 16% in group one to only 1% in group two ( $P < 0.05$ ).

### Major Complications

Five patients (3.8%) were noted to have major complications after surgical repair (Table 8). These included three patients (2.3%) with meningitis and two patients (1.5%) with mucoceles. The incidence of meningitis showed no significant change between the two study groups.

### Minor Complications

Ten patients (8%) had postoperative wound infections (Table 9). All infections resolved with intravenous antibiotics. Seven patients (5%) were noted to have long-term frontal paresthesias, and five patients (4%) were found to have temporal nerve paresis. Fourteen patients (11%) had postoperative frontal bone irregularities. Diplopia in upward gaze was noted in six patients (5%). The incidence of minor complications was unchanged between the two study groups.

### Postoperative Pain

Prolonged frontal pain was noted in five patients (4.5%) (Table 10). Two patients (2%) reported mild pain, one (1%) moderate, and two (1.5%) severe. The incidence of persistent postinjury pain was unchanged between the two study groups.

## DISCUSSION

The frontal sinus is absent at birth. In early childhood, the anterior ethmoid air cells invade the frontal bone and form the frontal sinus. It is radiographically identifiable at 8 years and matures to full size at approximately 15 years.<sup>6</sup> Fifteen percent of individuals have a unilateral sinus, and 4% have no frontal sinus at all. The posterior table of the frontal sinus is thin (0.1-4.8 mm) and usually offers little protection to the intracranial contents. The anterior table of the frontal sinus averages 2 to 12 mm in thickness and requires approximately 800 to 1,600 ft-lb of pressure for a fracture to occur.<sup>1</sup> It is more resistant to fracture than any other facial bone. Consequently, the majority of frontal sinus fractures are secondary to high-velocity impacts. There is significant risk of associated facial fractures, brain injury, and CSF fistula.

**Table 5**  
Associated soft-tissue injuries

	Wallis et al (1974-1986)	Current study (1987-2002)	P value
CSF leakage (%)	22 (31)	14 (11)	0.0004
Brain visible in wound (%)	9 (13)	4 (3)	0.01
Pneumocephalus (%)		34 (26)	
Cerebral contusion (%)		23 (18)	
Dural tear (%)		18 (14)	
Epidural hematoma (%)		10 (8)	
Intraparenchymal hemorrhage (%)		9 (7)	
Subarachnoid hemorrhage (%)		8 (6)	
Subdural hematoma (%)		5 (4)	
CSF leak (after fracture repair) (%)	7 (10)	6 (5)	0.22
Stopped spontaneously (%)	3 (4)	5 (4)	
Required surgery (%)	4 (6)	1 (1)	

**Table 6**  
**Surgical approach**

Incision	Wallis et al (1974-1986)	Current study (1987-2002)	P value
Coronal (%)	35 (48)	109 (84)	<0.0001
Extension of laceration (%)	24 (34)	19 (14)	0.004
Brow (%)	12 (16)	1 (1)	<0.0001
Lynch (%)	1 (2)	1 (1)	1.0

Approximately two-thirds of frontal sinus fractures involve a combination of the anterior table, posterior table, and/or the frontal recess. One-third are limited to the anterior table. Isolated posterior table fractures are rare.<sup>2</sup> Surgical repair of isolated anterior table fractures is primarily an aesthetic issue and is generally achieved with open reduction and internal fixation.<sup>3</sup> However, endoscopic surgical techniques have recently been described.<sup>7</sup> Surgical treatment of posterior table fractures is more controversial. Surgeons often disagree on indications for observation, obliteration, or cranialization of the sinus. We present a review of all patients treated for frontal sinus fractures between 1987 and 2002 and compare the data with patients collected from the same institution between 1974 and 1986. Changes in patient demographics and treatment patterns are discussed.

## Demographics

The incidence of frontal sinus fractures seen at UC Davis has increased from 6 per year between 1974 and 1986 (group 1, Wallis et al) to 8.7 per year between 1987 and 2002 (group 2, current study). Although the most common fracture etiologies have not changed from the initial study, there is a statistically significant change in the proportion of these injuries. Motor vehicle accidents remain the most common cause of frontal sinus fractures; however, the incidence has fallen significantly. Minimum seat belt requirements for passenger cars were established by the United States Congress in 1963. Automatic restraint systems with shoulder harnesses were mandated in the 1970s. However, during the initial study (1974-1986) seat belt laws were not actively enforced. Aggressive enforcement of seat belt laws

did not occur in California until the mid-1990s (midway through the second study period). Air bags became standard equipment on many vehicles in 1988. A law requiring air bags in all passenger cars and trucks was passed in 1998, toward the end of the second study period. There was a significant increase in the number of frontal sinus fractures resulting from personal assaults. This increase may be associated with a peak in violent crimes (documented by the California Department of Justice) seen in the early 1990s.

## Fracture Type

Comparing groups 1 and 2, "through and through" fractures decreased, anterior/posterior table fractures increased, and there was no significant change in the number of isolated anterior table, isolated posterior table, or frontal recess fractures (Table 2). The reduction in through and through fractures implies that the inciting injury was less severe and that the fractures were isolated to the sinus itself. Consequently, more patients presented with anterior/posterior table fractures. The most likely etiology of this change is the advent of air bags, and the increased use of seat belts (see demographics). There was a corresponding decrease in the severity of associated soft-tissue injuries (Table 5). The incidence of CSF leak and brain visible within the wound on presentation both dropped. These changes are also attributable to seat belt laws and air bags.

## Associated Fractures

There was a significant increase in the number of associated facial fractures between group 1 and group 2 (Table 3). This finding would seem contradictory to the reduced severity of injuries noted previously. However, this difference is most likely explained by the improved sensitivity of CT scans between the 1970s and 2002. From 1974 to 1984, UC Davis used rectilinear CT scanners that offered a minimum slice thickness of 5 mm. A full-face CT scan took approximately 4.5 minutes, which predisposed the study to motion artifact. These two factors undoubtedly reduced the sensitivity of the CT scans performed early in the study. In 1984, whole-body, ring detector CT scanners were introduced at UC Davis, reducing the cut thickness to 3 mm. Scan times were still approximately 3 minutes. In 1993, "slip ring" technology with single-row helical scanning became available.

**Table 7**  
**Surgical repair**

Procedure	Wallis et al (1974-1986)	Current study (1987-2002)	P value
Cranialization (%)	30 (41)	27 (21)	0.002
Osteoplastic flap and fat obliteration (%)	24 (33)	92 (71)	<0.0001
Open reduction and internal fixation of anterior table (%)	14 (20)	8 (6)	0.008
Ablation (%)	2 (5)	0	0.12
Exploration only (%)	1 (1)	3 (2)	1.0
Intersinus septectomy (%)	1 (1)	0	0.4

**Table 8**  
**Major complications**

Complication	Wallis et al (1974-1986)	Current study (1987-2002)	P value
Meningitis (%)	4 (5.6)	3 (2.3)	0.25
Mucocele (%)	4 (5.6)	2 (1.5)	0.18

This reduced minimum cut thickness to 1.0 mm, with a scan time of 30 seconds. Multidetector (4-row), submillimeter scanning was introduced at UC Davis in 1999, allowing a facial CT scan to be performed in 10 to 12 seconds. Although it is possible that the number of associated facial fractures increased between the two study groups, we believe this is very unlikely. The best explanation is that the sensitivity of CT scanning has simply allowed more accurate diagnosis of these injuries.

## Treatment

**Surgical approach.** The most commonly used surgical approach varied significantly between group 1 and group 2 (Table 6). The use of a coronal incision increased, whereas access through extension of an existing laceration or a brow incision decreased. These findings are best explained by changes in our surgical technique, specifically an increased emphasis on well hidden and more aesthetically pleasing incisions. Management of facial fractures has evolved from bandaging in the time of Hippocrates to intermaxillary splints and wiring in the late 1800s, open reduction and internal fixation with wire in the early 1900s, and finally internal fixation with rigid plates in the 1950s. It should be noted that the primary emphasis (even into the early 1980s) was on wide surgical access as well as reduction and fixation of the facial bones. In the late 1980s, a greater emphasis was placed on surgical outcomes (both aesthetic and functional). In the case of frontal sinus fractures, access through forehead incisions or extension of smaller lacerations gave excellent exposure but resulted in postoperative paresthesias and poorly hidden scars. Therefore, surgeons moved to the coronal incision, which offered improved aesthetics and reduced postoperative paresthesias.

**Surgical repair.** The method of fracture repair also changed significantly between the study groups (Table 7). Cranialization decreased and sinus obliteration increased. This change is very consistent with the reduced severity of injury previously noted. Cranialization is generally reserved for fractures with marked posterior table disruption, and obliteration is used for moderately severe fractures involving both the anterior and posterior tables. However, this does not entirely explain the data. The number of patients treated with open reduction and internal fixation also decreased with no significant change in the number of isolated anterior table fractures. This paradoxical trend is most likely related to new surgeons joining the faculty at UC Davis and having different criteria for internal fixation versus obliteration.

## Complications

The incidence of meningitis showed no significant change between the 2 study groups, despite the decreased severity of injuries (Table 8). The incidence of mucocele formation is extremely difficult to assess because mucoceles rarely develop soon after the injury. It commonly takes 5 to 10 years before these patients present and therefore rarely return to the treating institution. The current study revealed no significant difference in mucocele formation between the two groups. The incidence of minor complications and persistent postinjury pain were unchanged (Tables 9 and 10).

## CONCLUSION

Frontal sinus fractures continue to be a significant cause of morbidity among trauma patients treated at the University of California, Davis. The number of patients presenting with frontal sinus fractures increased from 6 per year in group 1 (1974-1986) to 8.7 per year in group 2 (1987-2002). The most common fracture etiologies have not changed. However, there was a statistically significant reduction in the number of patients presenting with frontal sinus fractures after being involved in motor vehicle accidents. This change is most likely related to more aggressive enforcement of seat belt laws and the advent of air bags. There was also a significant increase in the number of patients who presented

**Table 9**  
**Minor complications**

Complication	Wallis et al (1974-1986)	Current study (1987-2002)	P value
Wound infection (%)	7 (10)	10 (8)	0.60
Paresthesia (%)	6 (8)	7 (5)	0.55
Deformity (%)	6 (8)	14 (11)	0.63
Not treated (%)	1 (1)	9 (7)	
Treated surgically (%)	5 (7)	5 (4)	
Diplopia on upward gaze (%)	1 (1)	6 (5)	0.42
Temporal nerve paresis (%)	Not recorded	5 (4)	

**Table 10**  
**Postoperative pain**

Postoperative pain	Wallis et al (1974-1986)	Current study (1987-2002)	<i>P</i> value
Mild (%)	3 (4)	2 (2)	0.7
Moderate (%)	1 (1)	1 (1)	0.7
Severe (%)	1 (1.4)	2 (1.5)	0.7

with frontal sinus fractures after assault. This increase correlates with California Justice Department data showing a spike in personal assaults seen in the 1990s. Finally, the severity of frontal sinus fractures was less in group 2 than group 1. There was a significant reduction in the number of patients presenting with “through and through” fractures as well as associated intracranial injuries. There was a corresponding increase in the number of patients presenting with fractures limited to the frontal sinus itself (ie, anterior/

posterior table fractures). These changes are most likely related to seat belt laws and the advent of air bags.

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