Incidence, patterns, and management of frontal sinus fractures

A 10-year retrospective study at a tertiary medical center, Saudi Arabia

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ABSTRACT

الأهداف: تقييم نسبة حدوث الانماط المختلفة من كسور الجيوب الجبهية و العلاقة بين هذه الكسور و طرق العلاج و المضاعفات المتوقعة. كسور الجيوب الجبهية غالباً ماتكون مصاحبة لإصابات الأنسجة الرخوة والصلبة و أذى لمكونات الجمجمة.

المنهجية: دراسة استرجاعية أجريت في مدينة الملك سعود الطبية بالرياض، المملكة العربية السعودية. الدراسة حللت سجلات المرضى الذين شخصوا بكسور الجيوب الجبهية وتم علاجهم في الفترة مابين 2011م و 2021م. معايير الإستثناء في الدراسة كانت السجلات غير المكتملة أو المرضى الذين لم يستكمل علاجهم. البيانات المسترجعة شملت عمر المريض، الجنس، نوع و موضع الكسر، و العلاج و المضاعفات الناتجة عن كسور الجيوب الوجهية. البيانات حللت باستخدام برنامج الأس بي أس أس الأحصائي النموذج 23.0.

النتائج: من بين 72 مريض شملتهم الدراسة، 94.4% من المرضى كانوا ذكور و 5.6% كانوا من الاناث. (91%) من المرضى كانت اصاباتهم نتيجة لحوادث السير. نسبة كسور الجيوب الجبهية في جانب واحد كانت في 59.7% من المرضى و نسبة الكسور المصاحبة لإصابات أخرى كانت في 80.6% من الحالات. كسور العظمة الجبهية الأمامية منفردة كانت الأعلى حدوثا (58.3%) تلتها الكسور التي شملت العظمة الجبهية الأمامية و الخلفية في آن واحد بنسبة (37.5%). من بين المرضى الذين عولجوا جراحياً، كان ازالة بطانة الجيوب الجبهية في (23.9%) من الحالات، و (23.9%) بإزالة البطانة و العظمة الخلفية للجيوب الجبهية و (52.2%) بالتثبيت الجراحي فقط. قسمت المضاعفات إلى: مضاعفات عصبية بنسبة (22.2%)، مضاعفات عينية (15.3%)، مضاعفات تلوث (2.8%)، و مضاعفات تشوهية (16.7%). الكسور التي شملت العظمة الأمامية و الخلفية في ان واحد كانت الأعلى في نسبة حدوث المضاعفات.

الخلاصة: معظم حالات كسور الجيوب الجبهية استوجبت العلاج الجراحي بنسبة (63.9%). مضاعفات مابعد التدخل الجراحي سجلت في أكثر الحالات و كانت مضاعفات عصبية و عينية على الأغلب. ننصح بتركيز الدراسات المستقبلية على تقييم العلاقة بين المضاعفات والمواد المستخدمة بعد إزالة الطبقة المبطنة للجيوب الجبهية.

Objectives: To assess the prevalence of various frontal sinus fractures (FSF) and examine the relationships between these fractures, types of treatments, and potential complications.

Methods: A retrospective study was carried out in King Saud Medical City, Riyadh, Saudi Arabia. The study analyzed the records of patients who were diagnosed and treated with FSF from 2011-2021. Files with missing documents or incomplete treatment were excluded. The retrieved data includes: patients age, gender, types, locations, treatment, and complications of FSF. Data was analyzed by the statistical Package for the Social Sciences Statistics, version 23.0 using descriptive statistics and Chi-square test.

Results: A total of 72 cases were included, 94.4% males and 5.6% females. Road traffic accidents were the common cause of trauma (91%). Frontal sinus fractures were unilateral in 59.7% and associated other injuries in 80.6% of cases. Anterior table fractures were the largest proportion (58.3%), followed by anterior and posterior table (37.5%). The carried out surgical procedures were obliteration (23.9%), cranialization and obliteration (23.9%), and fixation only (52.2%). The post-operative complications were categorized into; neurological (22.2%), ophthalmic (15.3%), infection (2.8%), and deformity (16.7%). Anterior and posterior table had the highest percentage among these categories.

Conclusion: Frontal sinus fractures were mostly required surgical treatment (63.9%) and post-operative complications occurred especially the neurological and ophthalmic. We recommend studies on the association of complications and different types of obliteration materials.

Keywords: frontal fractures, fixation, obliteration, cranialization

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The frontal sinus locates in the upper third of the facial skeleton, and begins to grow in the fourth week of pregnancy and continues to do so until adulthood. The frontal sinus can be assessed on radiographs by the age of 8 years, and it fully develops by the age of 12.[1]

The anterior and posterior frontal sinus walls have different functions. While the anterior frontal sinus bone is significantly thicker and shapes the esthetic contour of the forehead, the posterior frontal wall is thinner and functions to protect and separate the cranial vault from the sinus and its contents.[2]

The drainage of the frontonasal ducts takes place through the nasal cavity by the middle meatus. The frontal sinus is covered by pseudo stratified ciliated columnar epithelium tissue that is intermixed with goblet cells which are responsible for mucus production.[1]

The Frontal bone is considered to be one of the strongest bones in the maxillofacial area and needs a force from 800-2200 lbs to be fractured. These fractures are usually associated with soft and hard tissues injuries and intracranial insults.[3]

The literature includes variable incidence of frontal sinus fractures (FSF) among different countries. According to a study by Almasri et al[4] carried out in the Southern region of Saudi Arabia in 2013, FSF and naso-ethmoid orbital complex fractures accounted for approximately 21.91% of maxillofacial fractures. A recent study in 2022, Riyadh, Saudi Arabia, by Asiri et al[5] reported that 14.75% of the maxillofacial fractures were FSF. Roden et al[6] found that FSF represented 37% of the total facial fractures in North Carolina trauma center, United States. In contrast to the high percentage of the previous study, Ludi et al[7] reported that 8.2% of facial fractures were frontal fractures in Emory University, United States.

There is a high tendency for frontal fractures to involve the male gender, according to studies from different places. Strong et al[8] and Al-Shami et al[9] found that men were involved in 89% and 84% of frontal fractures. Similarly, Johnson et al's systematic review and meta-analysis showed that 84.1% of frontal fractures occurred in men.[10]

Road traffic accidents were the common cause of frontal fractures in multiple studies and the percentages range from 52-75%.[8,9]

The location and configuration of FSF determine the treatment type. It can be treated conservatively with medication prescriptions and follow-up, or surgically with cranialization, obliteration, or internal fixation only.[3]

While FSF occur less frequently than other maxillofacial injuries, and there are several treatment options available for it, the complications are severe and almost inevitable. Frontal fractures may result in: meningitis, sinusitis, infection, leakage of cerebrospinal fluid (CSF), hematoma, contour irregularities, brain abscess, meningitis, mucoceles, muopyoceles, and chronic headache.11

The purpose of this study was to assess the prevalence of various FSF and examine the relationships between these fractures, types of treatments, and potential complications. The data was retrieved from King Saud Medical City in Riyadh, Saudi Arabia, which is one of Saudi Arabia's busiest and largest trauma centers.

Methods. A retrospective study was carried out to analyze the records of patients who were diagnosed with FSF and treated in King Saud Medical City, Riyadh, Saudi Arabia. The study was approved by the institutional review board of Riyadh Elm University, Saudi Arabia, and registered with the number: FPGRP/2021/619/542. Additionally, King Saud Medical City, Riyadh, Saudi Arabia, research committee approved this study and registered it with IRB number: H-01-R-053.

Patients in all ages with FSF that were treated in King Saud Medical City, Riyadh, Saudi Arabia, from 2011-2021 were included in the study. Exclusion Criteria were files with incomplete or missing documents or the patients who had incomplete treatment.

The included patients were diagnosed with FSF based on axial and coronal computed tomography scans upon admission. The retrieved data included: patients age, gender, patterns of FSF (isolated or associated with other facial injuries), fracture location (unilateral or bilateral), type of fracture (anterior, combination of anterior and posterior, or posterior table).

The study reviewed the type of treatment procedure, whether it was conservative or surgical. The treatment was considered conservative when surgical intervention was not required and the patient was discharged under medications; analgesics, and antibiotics with regular follow-up, or under other concern teams such as neurosurgery or ophthalmology. If the treatment was surgical, the following variables were documented; time of surgery, and types of the used procedures. The documented complications wither following the trauma or the surgical procedures were retrieved. The study analyzed the correlation between the presence of complications and other variables.

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Statistical analysis. The data was analyzed by the Statistical Package for Social Sciences, version 23.0 (IBM® Corp., Armonk, NY, USA). Descriptive statistics were carried out for all the variables of the study. The Chi-square test was employed to compare the percentages/frequencies between the groups. Significance level was set at $p \leq 0.05$.

Results. The retrieved files revealed that 115 cases fulfilled the criteria of the study. A total of 43 cases were excluded due to incomplete data. Accordingly, 72 cases were included, 68 (94.4%) males and 4 (5.6%) were females. The mean age of all the participants was 27.6 years. Road traffic accidents was the cause of trauma for 66 (91%) patients, followed by 4 (5.6%) cases of assaults, one (1.4%) fall, and one (1.4%) explosion. The patterns, types, and the anatomical locations of frontal fractures are shown in Table 1.

A total of 46 (63.9%) patients underwent surgical procedures, while 26 (36.1%) underwent conservative treatment. Three groups were recognized for the surgical management; 11 (23.9%) patients had obliteration and fixation (OF); 11 (23.9%) patients had cranialization in conjunction with obliteration and fixation (COF); and 24 (52.2%) patients received fixation just for cosmetic purposes (FIX) because they had no post-trauma complications.

After 48 hours of trauma, 95.7% of patients who underwent surgery had that procedure carried out. Coronal flaps provided the required access for 36 (78.3%) patients, whereas the existing wounds were used for the remaining patients (21.7%).

A total of 24 (52.2%) patients had a titanium plate as their fixation device, while 17 (37%) patients had a combination of titanium plate and titanium mesh; and 5 (10.8%) patients had titanium mesh alone.

Table 1 - The distribution of patterns, locations, and types of frontal bone fractures.

Frontal bone fractures	n (%)
Pattern of fractures	
Associated	58 (80.6)
Isolated	14 (19.4)
Location of fracture	
Bilateral	29 (40.3)
Unilateral	43 (59.7)
Type of fracture	
Anterior	42 (58.3)
Anterior and posterior	27 (37.5)
Posterior	3 (4.2)

Values are presented as numbers and percentages (%).

A total of 30 (41.6%) out of 72 patients experienced one or more complications. A total of 22 (47.8%) out of 46 patients who underwent surgery experienced complications, while only 8 (30.8%) out of 26 patients who was treated conservatively had complication, but the different was insignificant (p=0.215).

Approximately 86% of the frontal fractures that were recorded had some other face injuries associated with them. As a result, the observed consequences like ophthalmic complications, could be caused by the associate other trauma. The reported complications after treatment were categorized into 4 groups; neurological, ophthalmic, infection, and facial deformity, each one has different variables. The frontal fractures that involved both anterior and posterior walls had the highest percentage of complication (55.6%), while the posterior wall had 33.3%, and the anterior wall had 31%. The percentages of complications associated types of fractures are shown in Table 2. The associations between the different types of treatment and the variant complications are shown in Table 3. The reported complications were classified into 2 categories based on the timing; early, occurred within 6 months of the trauma, and late, occurred after 6 months (Table 4).

Discussion. Frontal sinus fractures represent a small percentage compared to other maxillofacial fractures, but still can lead to serious extracranial and intracranial conditions.[12] Investigating the cause, the location of fracture, and the involved structures can determine the treatment option and minimize the possible complications.[13]

The demographics of the involved patients in our study showed a higher incidence of FSF among males (94.4%) compared with females (5.6%). This came as a result of the majority of drivers in Saudi Arabia being men. In the same way, Gonty et al's study revealed that 93.9% of patients with frontal fractures were men and 6.1% were women.[14] Moreover, Montovani et al[15] found 95.8% of patients were males and 4.2% females.

Our study reported motor vehicle accidents as the most common cause of fracture (91.7%), which was higher than the previous published studies.[8,12,14,15] According to them, frontal fractures were most frequently caused by motor vehicle accidents (63%, 57.6%, 52%, and 58.3%).[8,12,14,15]

Assault accounted for only 5.6% of the cases in the current study, making it the second cause of trauma. In the study of Strong et al[8] which was carried out in 2006, California, United States and the Johnson et al[10] systematic review and meta-analysis, assaults were also the second cause; however, the percentages were higher (26% and 13%).

Table 2 - The reported complications with different types of frontal fractures.

Complications	All patients (n=72)	Anterior (n=42)	Anterior & posterior (n=27)	Posterior (n=3)	*P*-values
Neurological					
Seizures	2 (2.8)	-	2 (7.4)	-	0.180
Facial weakness	4 (5.6)	3 (7.1)	1 (3.7)	-	0.327
Headache	4 (5.6)	2 (4.8)	2 (7.4)	-	0.817
CSF leak	1 (1.4)	-	1 (3.7)	-	0.430
Facial paresthesia	2 (2.8)	1 (2.4)	1 (3.7)	-	0.907
Epilepsy	2 (2.8)	-	2 (7.4)	-	0.180
Anosmia	1 (1.4)	1 (2.4)	-	-	0.696
Total	16 (22.2)	7 (16.7)	9 (33.3)	-	0.171
Ophthalmic					
Diplopia	6 (8.3)	4 (9.5)	2 (7.4)	-	0.827
Ptosis	1 (1.4)	-	1 (3.7)	-	0.430
Epiphora	2 (2.8)	1 (2.4)	-	1 (33.3)	0.696
Enophthalmos	1 (1.4)	-	1 (3.7)	-	0.430
Optic nerve injury	1 (1.4)	-	1 (3.7)	-	0.430
Total	11 (15.3)	5 (11.9)	5 (18.5)	1 (33.3)	0.511
Infections					
Infected wound	1 (1.4)	-	1 (3.7)	-	0.430
Osteomyelitis	1 (1.4)	-	1 (3.7)	-	0.430
Total	2 (2.8)		2 (7.4)	-	0.181
Facial deformity	12 (16.7)	7 (16.7)	5 (18.5)	-	0.717

Values are presented as numbers and percentages (%). The percentages were calculated within the fracture type.
CSF: cerebrospinal fluid

We reported that the FSF were accompanied with other maxillofacial fractures and injuries in 80.6% of the cases. This outcome corroborated the findings of Gerbino et al[12] who discovered that FSF were associated with 58.2% of other maxillofacial fractures.

According to our data, the proportion of unilateral fractures was 59.7%. This was in line with the findings of Firouzbakht et al[16] who found that unilateral fractures occurred more frequently (73.9%) than bilateral fractures (26.1%).

We found that anterior table fractures accounted for the largest proportion of fractures (58.3%), followed by anterior and posterior table fractures (37.5%), while the posterior table fractures accounting for only 4.2% of cases. There is a high incidence of fractures on the anterior table because it is the first region in the frontal area to receive trauma. These findings agreed with Gonty et al[12] who found 63.6% of fractures in anterior table, 33.3% in combined fractures of anterior and posterior table, and 3.1% in isolated posterior table fractures and Gerbino et al[14] who found 61.4% of fractures in anterior table, 33% in combined fractures of anterior and posterior table, and 0.6% in isolated posterior table fractures. However, these findings were at disagreement with those of Rodriguez et al[17] who discovered a high percentage of fractures (54.8%) in the combined anterior and posterior tables.

Of all the patients included in this study, the neurologic group of complications had the highest percentage (22.2%), followed by ophthalmic complications (15.3%). The most frequent complication was diplopia, which occurred in 8.3% of patients, however, the reported ophthalmic complications might present due to the associated facial injuries. Other common complications included facial deformity (16.7%), headache (5.6%), facial weakness (5.6%), paresthesia (2.8%), and wound infection (1.4%). According to Strong et al[8] approximately 5% of patients had diplopia, 11% had facial deformity, 4% had facial weakness, 5% had paresthesia, and 8% had wound infections.

Our results showed that late complications were reported in only 14% of patients which include; 5.6% facial deformity, 4.2% headache, 1.4% facial paresthesia, 1.4% anosmia, and 1.4% osteomyelitis. Strong et al[8] observed late complications in 11.9% of patients.

Our study analyzed the association between the fracture types and the variant complications. A large percentage of neurological complications (33.3%), ophthalmic complications (18.5%), infection (3.7%), and facial deformity (18.5%) were associated with frontal fractures that affected both the anterior and posterior walls. This can be explained by the severity of head and cranial injuries in this type of fracture, which is also require complicated surgical interventions. Facial weakness, anosomia, diplopia, and epiphora were the exceptions, as they had higher percentages in anterior

Table 3 - The reported complications with different types of treatment.

Complications	Conservative treatment (n=26)	Surgical treatment (n=46)			*P*-values
		COF (n=11)	OF (n=11)	Fixation only (n=24)	
Neurological					
Seizures	-	1 (9.1)	-	1 (4.1)	0.415
Facial weakness	-	1 (9.1)	1 (9.1)	2 (8.3)	0.492
Headache	-	1 (9.1)	1 (9.1)	2 (8.3)	0.492
CSF leak	-	1 (9.1)	-	-	0.131
Facial paresthesia	-	-	-	2 (8.3)	0.249
Epilepsy	-	1 (9.1)	1 (9.1)	-	0.197
Anosmia	-	-	-	1 (4.1)	0.567
Total	0 (0.0)	5 (45.4)	3 (27.3)	8 (33.3)	0.005
Ophthalmic					
Diplopia	3 (11.5)	-	-	3 (12.5)	0.408
Ptosis	-	-	1 (9.1)	-	0.131
Epiphora	1 (3.8)	-	-	1 (4.1)	0.832
Enophthalmos	-	-	-	1 (4.1)	0.567
Optic nerve injury	-	1 (9.1)	-	-	0.131
Total	4 (15.4)	1 (9.1)	1 (9.1)	5 (20.8)	0.391
Infections					
Infected wound	-	1 (9.1)	-	-	0.131
Osteomyelitis	-	1 (9.1)	-	-	0.131
Total	0 (0.0)	2 (18.2)	0 (0.0)	0 (0.0)	0.010
Facial deformity	4 (15.4)	2 (18.2)	-	6 (25)	0.327

Values are presented as numbers and percentages (%). The percentages were calculated within the type of treatment.
COF: cranialization with obliteration and fixation, OF: obliteration and fixation, CSF: cerebrospinal fluid

Table 4 - Early and late complications.

Complications	Early	Late	All patients (n=72)
Seizures	2 (2.8)	-	2 (2.8)
Facial weakness	4 (5.6)	-	4 (5.6)
Headache	1 (1.4)	3 (4.2)	4 (5.6)
CSF leak	1 (1.4)	-	1 (1.4)
Facial paresthesia	1 (1.4)	1 (1.4)	2 (2.8)
Epilepsy	2 (2.8)	0 (0.0)	2 (2.8)
Anosmia	-	1 (1.4)	1 (1.4)
Diplopia	6 (8.3)	-	6 (8.3)
Ptosis	1 (1.4)	-	1 (1.4)
Epiphora	2 (2.8)	-	2 (2.8)
Enophthalmos	1 (1.4)	-	1 (1.4)
Optic nerve injury	1 (1.4)	-	1 (1.4)
Infected wound	1 (1.4)	-	1 (1.4)
Osteomyelitis	-	1 (1.4)	1 (1.4)
Facial deformity	8 (11.1)	4 (5.6)	12 (16.7)

Values are presented as numbers and percentages (%).
CSF: cerebrospinal fluid

frontal wall fractures. Out of the 3 cases of posterior wall fracture, one case of epiphoria was reported, however, the small number of cases makes the percentage unreliable.

A case of CSF leakage out of 11 (9.1%) patients, was reported, following COF therapy in this study. A total of 9 (12.5%) patients had a reported CSF leak at the time of admission. These results were less than those of Gerbino et al[12] which was 24.7% and Dalla Torre et al[18] which was 29.2%. However, Strong et al[8] found that 11% of cases had CSF leaks, which was close to our findings.

In this study, surgical treatment was carried out to the greater number of patients (63.9%). The coronal incision was used in 78.3% of cases, while existing wound used in 21.7%. These outcomes are comparable to those reported in the Strong et al[8] study, which showed that 84% surgical treatments involved coronal incisions and 14% involved of wounds that already existed.

We found the treated cases conservatively had the lower incidence of complications (26.9%) than cases that underwent surgery (47.8%). These results supported the study of Rodriguez et al[17] who found that conservative treatment had a 3.1% lower incidence of complications and the systematic review and meta-analysis of Al-Moraissi et al[19] who found that conservative treatment had a 7% lower incidence of complications.

The patients who received conservative treatment in the current study, did not experience any neurological complications. Nevertheless, these kinds of problems occurred in 5 (45.4%) out of 11 cases treated with

COF, and was higher than other surgical treatments. Ophthalmic complications presented in 5 (20.8%) out of 24 patients who were treated by FIX alone, while this type of complications was also recorded in 4 (15.4%) out of 26 patients who had conservative treatment. Only 2 cases of infection was reported in this study, both were in COF cases. The largest number of facial deformity was in patients who were treated only by FIX (25%).

In this study, OF and COF were utilized in 22 cases. However, several kinds of obliteration materials were used, and many cases involved one, 2, or more materials. Local flaps were used including pericranial flaps and temporalis muscles. In some cases, facia or fats were used without mentioning its origin. Various materials were utilized. However, their descriptions were inadequate and lacked full scientific titles or brand names (namely, bone adhesive, bone wax, surgicel, fibrine patches, gelfoam, bioglue, bone glue, or bone wax).

The usage of antibiotics was the subject of another documentation deficit. Reviewing the patient records revealed that there was no specific protocol for antibiotics coverage. Additionally, in polytrauma situations, different types of antibiotics were given by surgeons from other specialties.

Study limitations. Inadequate hospital documentation regarding the obliteration materials and the used antibiotics were limitations to this study. As a result, we advise more attention to precise data recoding that will aid in upcoming research on the impact of various obliteration materials the selected antibiotics on the frequency of complications.

In conclusion, the majority of FSF were caused by motor vehicle accidents. They were commonly unilateral, and accompanied with other maxillofacial injuries in over 80% of the cases. The fractures in anterior table were more common. However, complications were more when anterior and posterior tables were fractured.

Frontal bone fractures were mostly required surgical treatment (63.9%). Post treatment complications are expected especially the neurological (22.2%) and ophthalmic (15.3%). We recommend studies on the association of different types of obliteration materials and complications.

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