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RESEARCH ARTICLE

ASSESSING BONE HEALING IN PATIENTS WITH VARIOUS TYPES OF FACIAL BONE FRACTURES BY EVALUATING BONE BIOCHEMICAL MARKERS IN CONJUNCTION WITH RADIOGRAPHIC FINDINGS

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Abstract

Background and aims: When a bone fracture occurs, the bone matrix is damaged and destroyed, cells die, the periosteum and endosteum rip, and the ends of the broken bone may move. Cascades of biological processes are necessary for bone development and healing. Numerous biological indicators found in blood and tissue fluids may be helpful in assessing how well bone mending is going. By analysing bone biochemical indicators in connection to radiographic results, this study aims to assess bone healing in patients with various forms of facial bone fractures.

Patients and methods: A clinical laboratory study conducted in 2025 at Military Hospital in Sana'a, Yemen, included twenty patients with surgically treated facial bone fractures. The study documented injury types, fracture sites, and treatment methods. Radiographic assessments were performed upon admission and during postoperative follow-ups. Blood samples were collected at zero days, 14, 45, and 90 days for biochemical analysis of alkaline phosphate (ALP) activity, calcium, phosphorus, and c-reactive protein (CRP) levels in serum.

Results: The study comprised 20 patients, predominantly male (80%) with an average age of 37.6 years, mainly suffering fractures from road traffic accidents (85%). The zygomatic bone was most frequently affected (55%). Fracture types included compound (40%), comminuted (35%), and simple (25%). Postoperatively, 80% had open reduction, with nerve injury as the sole complication (10%).

Conclusions: Fracture causes mainly stemmed from road traffic accidents; the zygomatic bone was the most frequently fractured site. Fracture types included compound was the most common, most patients underwent open reduction, and the only complication noted was nerve injury. Serum and biochemical markers can be used for evaluation of progress of bone formation and help clinician to assess the type of treatment.

Keywords: Alkaline phosphate, biochemical markers, calcium, C-reactive protein**,** facial bone fracture, phosphorus.

INTRODUCTION

Ten to twenty-five percent of all skeletal injuries are facial bone fractures, with considerable variation based on socioeconomic class and geographic location. Mandibular fractures are the most prevalent (40–60%), followed by Le Fort fractures (I–III) involving the maxilla and midfacial fractures (zygomaticomaxillary complex, orbital wall, naso-orbito-ethmoidal fractures). The causes are varied and include falls (10–20%), sports injuries (5–15%), interpersonal violence (20–40%), and road accidents (30–50%)[1]. Minor nondisplaced fractures may be treated conservatively, although open reduction and internal fixation (ORIF) with plates and screws is the usual course of treatment[2]. Although the average healing period is 6–12 weeks, problems like infection, malunion, and non-union can make recovery take longer, particularly for patients who smoke, drink alcohol, or have concomitant conditions like diabetes or osteoporosis[3]. In Yemen, the most every day reasons are traffic accidents and inter personal violence[4-7], while in other areas as in Asia occupational accidents and falls dominate the statistics[8].

One of the most complicated and significant injuries in craniofacial trauma are facial bone fractures, which cause significant functional deficiencies of the stomatognathic system in addition to structural and cosmetic impairment[1-3]. The clinical care of these fractures is still difficult despite advancements in radiological imaging and surgical procedures, especially when it comes to tracking bone regeneration and forecasting healing results. Opportunities for early intervention are limited because current diagnostic standards, including as radiography and CT scans, sometimes only identify abnormal healing at advanced stages[1,9,10]. A physiologic process that involves inflammation, cellular proliferation, callus development, and remodelling, bone healing is extremely dynamic and strictly controlled[11]. A key idea in relation to osteoporosis hip fractures is bone quality. It understands bone composition, which includes minerals, proteins, and cells, as well as bone structure. Because of its crucial structural role in bone mineralisation and metabolic equilibrium, calcium (Ca) exerts an anti-fracture effect[12,13]. At various stages of the fracture healing process, there are some fluctuations in serum calcium levels[14]. The ability of calcium transit, reservation, bone metabolism, and restoration may be represented by variations in serum calcium levels[15].

One indicator of bone development is alkaline phosphatase (ALP). ALP is extensively present in the liver, kidney, and bone, among other organs. About half of serum ALP comes from the liver and the other half from osteoblasts[16,17]. Epidemiologic investigations have shown a negative correlation between serum C-reactive protein (CRP) levels and bone mineral density (BMD)[18,19]. As a result, CRP is probably connected to fracture risk and bone fragility.

This study was conducted to assess bone biochemical markers in correlation with radiographic findings in order to evaluate bone healing in patients with various types of facial bone fractures. This was done because many biological markers in tissues, fluids, and blood may be useful in evaluating the progress of bone healing.

PATIENTS AND METHODS

Twenty patients with facial bone fractures (4 females and 16 males) who were admitted to our hospital between January 2025 and December 2025 comprised the current cohort. The same physician treated all of the patients surgically. At the time of admission, after surgery, and at 14 days, 45 days, and 90 days after surgery, blood was drawn for laboratory testing at the Central Health laboratory. ALP (U/L), Ca (mg/dL), P (mg/dL), and CRP (mg/L) were measured in the serum samples, and the same laboratory performed regular tests for the biochemical parameters.

Ethical considerations

Every participant gave their written or verbal consent. Under registration number 2025-6, dated January 5, 2025, the Ethics Committee of the Military Hospital approved the study, which was carried out in compliance with the Declaration of Helsinki.

Inclusion criteria: First, the fracture must be in the Facial Bones caused by trauma; second, the patient must have received adequate follow-up (at least two follow-up visits after surgery or an initial consultation for 90 days; and the fracture must be confirmed by computed tomography.

Exclusion criteria: The study excluded patients with pathological fractures due to osteitis, radiation necrosis, cysts, or tumours; it also excluded patients with incomplete medical records and inadequate follow-up.

Clinical feature record

Data were collected from medical records, including age, sex, comorbidities, cause of fracture, anatomical location of the fracture, extent of tooth involvement along the fracture line, time between injury and consultation/treatment, type of treatment (small plate fixation with or without intermandibular fixation, or reconstruction plate with or without intermandibular fixation), antibiotic regimen, inferior alveolar nerve damage, and the occurrence and management of any complications. Clinical assessment was used to classify patients into treatment groups, taking into account variables such as fracture type, displacement, occlusion stability, patient adherence, and functional impairment. In borderline cases, judgments were influenced by the surgeon's opinion even when institutional standards were followed. Resident physicians were typically involved in both surgical procedures and follow-up treatment, although the extent of their involvement in each case was not specified.

Statistical Analysis

Standard descriptive statistics were applied when the findings were tallied. Numerical variables are summarised using mean values, whilst categorical variables are displayed as counts and percentages. Table 1 displays the enrolled patients' demographic information.

Table 1: Sex and age distribution of patients with facial bone fractures.

Characters	N (%)
Sex	
Male	16 (80)
Female	4 (20.0)
Total	20 (100)
Age groups (years)	
Less than 20 years	4 (20)
21 - 30 years	4 (20)
31-40 years	7 (35)
More than 40 years	5 (25)
Mean	37.6 years
SD	18.7 years
Median	33.5 years
Mode	30 years
Range	16 to 70

RESULTS

The study included 20 patients, 80% males and 20% females. The mean age of the patients was 37.6±18.7 years, with a range of ages from 16 to 70 years. Looking at the age groups, 20% were under 20 years old, 20% were 21–30 years old, 35 % were 31–40 years old, and 25% were over 40 years old. The most common cause of fractures was road traffic accidents (85%), followed by fall (10%), and assault (5%).

Table 2: Distribution of fracture causes in patients with facial bone fractures.

Characters	N (%)
Assault	1 (5)
Explosion	0 (0.0)
Fall	2 (10)
Gunshot	0 (0.0)
Pathology	0 (0.0)
Road travel accident	17 (85)
Total	20 (100)

Social habits of patients with facial bone fractures whose vital signs were assessed before and after fracture repair surgery. Smoking was recorded in 20% of all patients, and khat chewing in 85% of them. Table 3 shows the medical history in patients with patients with facial bone fractures whose biochemical markers were assessed before and after fracture repair surgery. Diabetic mellitus occurred in 20% of total patients while 80% were healthy (no systemic diseases occurred).

Table 3: Medical history in patients with patients with facial bone fractures.

Characters	N (%)
Diabetic mellitus	4 (20)
Bone disease	0 (0.0)
CVD	0 (0.0)
Healthy	16 (80)
Total	20 (100)

Table 4 shows the fracture sites in patients with facial bone fractures whose vital signs were assessed before and after fracture repair surgery. The most common fracture site was the zygomatic bone (55%), followed by the mandibular Symphysis (25%), the body of the mandible (20%), the condyle of the mandible (20%), and finally the angle of the mandible (15%). For the maxilla, Lefort fractures of type I occurred in 20%, type II in 10%, and type III in 10%.

Table 4: Site of the fractures in patients with facial bone fractures.

Sites	N (%)
Mandibular	
Condyle	4 (20)
Ramus	0 (0.0)
Body	4 (20)
Symphysis	5 (25)
Angle	3 (15)
Maxilla	
Lefort I	4 (20)
Lefort II	2 (10)
Lefort III	2 (10)
Nasal bone	2 (10)
Zygomatic	11 (55)
Total	20 (100)

Nasal fractures were also present in 10% of patients. Types of fractures in patients with facial bone fractures whose biochemical markers were assessed before and after fracture repair surgery. Compound fractures were the most common (40%), followed by comminuted fractures (35%), and then simple fractures (25%). Table 5 shows the degree of displacement in patients with facial bone fractures whose biochemical markers were assessed before and after fracture repair surgery. Minimally displacement was observed in 45% of patients, severe displacement in 40%, while no displacement was observed in only 15%.

Table 5: Degree of displacement in patients with facial bone fractures.

Characters	N (%)
Non-displaced	3 (15)
Minimally-displaced	9 (45)
Severely-displaced	8 (40)
Total	20 (100)

The treatment methods in patients with facial bone fractures whose biochemical markers were assessed before and after fracture repair surgery. Open reduction was done for 80% of the patients while closed reduction was done for only 20%. Table 6 shows the postoperative complications in patients with facial bone fractures whose biochemical indicators were assessed before and after fracture repair surgery. The only complication in these patients was nerve injury, which accounted for 10% of all patients.

Table 6: Post operative complications among patients with facial bone fractures.

Complications	Total N (%)
Infections	0 (0.0)
Plate screw failure	0 (0.0)
Malunion	0 (0.0)
Nerve injury	2 (10)
Total	2 (10)

Table 7 shows a comparison of vital signs during the follow-up periods for patients with facial bone fractures whose biochemical indicators were assessed before and after fracture repair surgery. The mean alkaline phosphatase (ALP) level was 123.3±99 IU/L, ranging from 50 to 400 IU/L postoperatively, then increased to 173.4±158 IU/L, ranging from 50 to 600 IU/L 14 days postoperatively. The peak ALP level was reached 45 days postoperatively, with a mean±SD 257.6 ±192.3 IU/L, ranging from 150 to 800 IU/L. After 90 days, the ALP level decreased to 143.1±94 IU/L, ranging from 100 to 409 IU/L. The mean serum calcium level was 8.7±2.2 mg/dL, ranging from 5 to 12 mg/dL postoperatively. It then increased to 14.8±15 mg/dL, ranging from 7 to 57 mg/dL, 14 days post-operatively, which was its highest level. The serum calcium level decreased to 9.8±0.98 mg/dL, ranging from 9 to 11 mg/dL 45 days postoperatively, and after 90 days, the mean±standard deviation was 10.3±0.9 mg/dL, ranging from 9 to 12 mg/dL. The mean serum (inorganic) phosphorus level was 5.3±2.7 mg/dL, ranging from 2 to 9.9 mg/dL post-surgery. It then stabilized at 5±3 mg/dL, ranging from 1 to 9.8 mg/dL, 14 days post-surgery.

Table 7: Comparison of biomarkers during follow-up periods for patients with facial bone fractures.

Biomarkers	Post-operative	After 14 days	After 45 days	After 90 days
Alkaline phosphate (ALP) IU/L				
Mean	123.3	173.4	257.6	143.1
SD	99	158	192.3	94
Median	90.5	135	209	115
Mode	50	107	220	100
Min-Max	50-400	50-600	150-800	100-409
Serum Calcium (mg/Dl)				
Mean	8.7	14.8	9.8	10.3
SD	2.2	15	0.92	0.9
Median	9	10	9.5	10
Mode	9	8	9	10
Min-Max	5-12	7-57	9-11	9-12
Phosphorus (inorganic) mg/dL				
Mean	5.3	5	4.4	5.2
SD	2.7	3	2.55	2.6
Median	4.6	4.3	4.3	4.8
Mode	3	1	1	9
Min-Max	2 - 9.9	1-9.8	1-8.1	2.1-9
C-reactive protein (CRP) mg/L				
Mean	4.3	34	7.7	3.9
SD	2.9	28	7.1	2.8
Median	3.2	26	5	2.9
Mode	3	3.2	3.5	1.1
Min-Max	1.2-9.9	3.2-82	2-25	1-11

There was little change in the (inorganic) phosphorus level, which was 4.4±2.55 mg/dL, ranging from 1 to 8.1 mg/dL, 45 days post-surgery. After 90 days, the mean±standard deviation was 5.2±2.6 mg/dL, ranging from 2.1 to 9 mg/dL. The mean C-reactive protein (CRP) level was 4.3±2.9 mg/L, ranging from 1.2 to 9.9 mg/L post-surgery. CRP peaked 14 days post-surgery, with a mean±standard deviation of 34±28 mg/L, ranging from 32 to 82 mg/L, and then decreased to 7.7±7.1 mg/L, ranging from 2 to 11 mg/L 45 days post-surgery. CRP decreased further 90 days post-surgery, with a mean±standard deviation of 3.9±2.8 mg/L, ranging from 1 to 11 mg/L.

DISCUSSION

Facial fractures are breaks in the bones of the face (jaw, nose, cheeks, eye socket) resulting from injuries caused by accidents, falls, or assaults. They often cause pain, swelling, and difficulty breathing. Treatment usually involves reconstructive surgery to realign the bones, and recovery typically takes 6 to 8 weeks, although many injuries can be treated within three weeks[20,21]. The 20 patients in the current study ranged in age from 16 to 70 years, with 80% of them being male and 20% being female. Their mean age was 37.6±18.7 years. According to earlier reports, facial fractures are more common in men than in women, with a constant peak in occurrence during young adulthood[4-7,22]. This is consistent with our predominately male population and younger ages. A second, less severe increase in incidence occurs among elderly persons (often over 70 or 80 years of age) due to falls, with a higher proportion of these injuries happening in women, whereas young adults typically suffer serious injuries from RAT accidents and violence[21]. The zygomatic bone accounted for 55% of all fractures in the current study, with the mandibular symphysis coming in second at 25%, the body at 20%, the condyle at 20%, and the angle at 15%. Lefort fractures of type I, type II, and type III affected the maxilla in 20%, 10%, and 10%, respectively. Additionally, 10% of patients had nasal fractures. Current findings are consistent with earlier research showing that the mandible was the most commonly fractured bone in numerous studies (often 35%–64% of cases), usually linked to assault or auto accidents[22-26]. However, in several studies, particularly in paediatric populations, nasal bone fractures were the most frequent face fracture[20,27,28]. Also, the zygomaticomaxillary complex (ZMC) is the second or third most common site, frequently fractured in motor vehicle accidents[21]. Compound fractures accounted for 40% of all fractures in the current study, with comminuted fractures coming in second at 35% and simple fractures at 25%. Current findings differ from those of recent research (2010–2025), which found that between 48.9% and 82.5% of all facial injuries are simple (or single/isolated) facial bone fractures. While many or complex fractures are frequently linked to significant trauma, such as auto accidents, simple fractures only involve one broken bone[29-31].

In this study, the mean alkaline phosphatase (ALP) level was 123.3±99 IU/L postoperatively, then increased to 173.4±158 IU/L 14 days postoperatively . ALP levels peaked 45 days postoperatively, with a mean±standard deviation of 257.6±192.3 IU/L. After 90 days, ALP levels decreased to 143.1±94 IU/L. These results indicate and confirm that alkaline phosphatase (ALP) is an important biomarker of bone formation during facial fracture healing. Its levels typically rise after injury, peaking during the active callus formation phase (14–45 days), and then gradually return to normal upon successful fracture healing (approximately 90 days)[32]. In cases of facial fractures, such as mandibular fractures, measuring the level of alkaline phosphatase enzyme in the blood is a non-invasive and cost-effective method for monitoring and supplementing radiographic findings and predicting healing outcomes. The results in this study indicated no complications of non-union or malunion in patients' bone fractures.

Obtained results are consistent with the chronological patterns of alkaline phosphatase (ALP) levels, which typically begin to rise 7–9 days after injury. They then peak approximately 3–6 weeks post-injury, coinciding with the onset of active bone remodelling. Subsequently, in cases of successful healing, ALP levels peak within the normal range and then decline. In contrast, cases of non-union or delayed healing exhibit a higher and sustained peak that remains elevated for more than 6 weeks[32,33]. In comparing mandibular fractures with maxillary fractures, studies have shown that serum alkaline phosphatase (ALP) levels are higher in patients with mandibular fractures compared to those with upper facial injuries (maxilla and zygomatic bone), particularly 15- and 30-days post-surgery[33]. Furthermore, regarding the treatment modality, patients treated with open internal fixation (ORIF) may exhibit different early ALP responses compared to those treated with closed mandibular and maxillary fixation (MMF). Studies indicate that MMF may lead to elevated basal alkaline phosphatase (Bs-ALP) levels in weeks 3 to 6, suggesting greater bone resorption[34,35]. In conclusion, the importance of early monitoring: ALP monitoring during the first 1-2 weeks can indicate the quality of fracture fixation, as small increases indicate successful fixation, while large and rapid increases may indicate inadequate fixation or be a response to it, resulting in prolonged healing[32,33].

In the current study, the mean serum calcium level was 8.7±2.2 mg/dL postoperatively. It then increased to 14.8±15 mg/dL 14 days postoperatively, its highest level. The serum calcium level decreased to 9.8±0.98 mg/dL 45 days postoperatively, and after 90 days, it reached 10.3±0.9 mg/dL. Obtained results are consistent with the fact that normal serum calcium levels, even in cases of facial bone fractures, generally range between 8.5 and 10.5 mg/dL. Although calcium levels may temporarily rise during the healing process (especially 15–30 days post-injury) as part of bone remodeling, they usually remain within the normal physiological range[36,37].

In the current study, the mean serum inorganic phosphorus level was 5.3±2.7 mg/dL postoperatively. It then stabilized at 5±3 mg/dL 14 days post-operatively. There was little change in the inorganic phosphorus level, which was 4.4±2.55 mg/dL 45 days postoperatively. After 90 days, the mean± standard deviation was 5.2±2.6 mg/dL. These results are consistent with previous studies indicating that the normal range for inorganic phosphorus (phosphates) in adults, which generally applies even in traumatic injuries such as facial fractures, is typically between 2.5 and 4.5 mg/dL[38,39]. Regarding the effect of bone healing, although fractures involve significant bone remodeling, inorganic phosphorus levels in the body often remain within normal ranges. Some studies suggest that in the months following a bone injury, blood phosphate levels may change as the body adapts to increased bone consumption, but this does not always significantly alter the normal range of blood phosphate. Furthermore, blood phosphorus levels do not always reflect the total phosphorus content of the body, as 85–90% of it is stored in bones[38,39].

During bone healing, phosphorus levels may fluctuate within or slightly outside the normal range. Some research indicates a significant increase in phosphorus levels, peaking around day 15 postoperatively, coinciding with chondrocyte proliferation and bone formation. In studies of patients undergoing long bone fracture repair (which can be indicative of severe skeletal injuries such as facial fractures), phosphorus levels between 3.7 and 5.6 mg/dL were observed during the recovery period. Similarly, acute injuries, such as severe burns or large fractures, can sometimes lead to a temporary decrease in blood phosphorus levels (hypophosphatemia) due to the increased cellular demand for phosphorus during tissue repair; however, levels usually return to normal rapidly with proper nutrition[40-42].

In the current study, the mean postoperative C-reactive protein (CRP) level was 4.3±2.9 mg/L. CRP levels peaked 14 days postoperatively, with 34±28 mg/L, and then decreased to 7.7±7.1 mg/L 45 days postoperatively. CRP levels decreased further 90 days postoperatively, with 3.9±2.8 mg/L. Obtained results are consistent with the fact that CRP levels are typically elevated after facial bone fractures due to inflam-mation, with preoperative levels averaging around 28.5 mg/L and peaking at approximately 73.2 mg/L on the second postoperative day, before gradually returning to normal[43]. Open fractures and more severe fractures (e.g., mandibular fractures) produce higher peaks. In previous studies, the main findings regarding C-reactive protein (CRP) levels in facial fractures showed that preoperative levels were often elevated and directly correlated with the time elapsed since the injury. Postoperatively, CRP levels peak significantly after surgical fixation (such as open internal fixation), reaching a high of approximately 73.2 mg/L on day 2. They then return to normal, generally declining towards the normal range by day 7, indicating healing[44]. Several studies have indicated that factors influence C-reactive protein (CRP) levels. For example, fracture fixation with rigid plates often leads to a faster decrease in CRP levels compared to other methods. Dexamethasone reduces the peak elevation by half on the first day postoperatively. While a slight increase in CRP levels after surgery is normal, a second sharp rise may indicate complications such as infection. In general, open and complex maxillofacial fractures show significantly higher and more persistent CRP levels compared to closed fractures[45].

Limitation of the study

The current study, which assesses facial bone healing using biomarkers and radiographic findings, suffers from limitations due to the significant interindividual variability in the levels of these markers, the lack of standardized reference values for different fracture types, and the slow appearance of healing signs on radiographs, which are often subjective. Furthermore, serological markers lack sensitivity to specific locations in facial bones, and radiographs frequently fail to reveal early stages of healing.

CONCLUSION

Fracture causes mainly stemmed from road traffic accidents; the zygomatic bone was the most frequently fractured site. Fracture types included compound was the most common, most patients underwent open reduction, and the only complication noted was nerve injury. Serum and biochemical markers can be used for evaluation of progress of bone formation and help clinician to assess the type of treatment. While radiological examination is the gold standard, serial ALP measurements provide earlier indications of bone metabolism and healing progress.

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AUTHOR'S CONTRIBUTIONS

Jahaf ASS: conceptualization, data organization, clinical and laboratory tests. **Al-Ashwal AA:** formal analysis, critical review. **Al-Rahbi LM:** conceptualisation. **Al-Shamahy HA:** formal analysis, critical review. Final manuscript was checked and approved by all authors.

DATA AVAILABILITY

Upon request, the associated author can furnish the empirical data that substantiated the study's findings.

CONFLICT OF INTEREST

None to declare.

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