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RESEARCH ARTICLE

MAXILLOFACIAL FRACTURES AT THE TIME OF HARDWARE REMOVAL: AETIOLOGY, SURGICAL THERAPY, IDENTIFICATION OF POSTOPERATIVE INFECTIONS, AND ANTIBIOTIC PATTERN OF ISOLATES

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Abstract

Background and Aims: A mandibular fracture, or jaw fracture, typically occurs at two sites in about 60% of cases, potentially limiting mouth opening and causing gum bleeding and misalignment of teeth. This study aimed to identify the bacterial causes of postoperative infections, the aetiology of fractures, surgical treatment, and the antibiotic resistance profile of bacteria from patients with maxillofacial fractures at the Military Hospital in Sana'a, Yemen.
Materials and Methods: The Department of Oral and Maxillofacial Surgery at the Military Hospital in Sana'a, Yemen, treated thirty patients with maxillofacial fractures from January to December 2024. They used fracture fixation hardware and conducted follow-ups six months post-surgery. The study assessed the incidence of postoperative bacterial infections at surgical sites after hardware removal, employing standard microbiological techniques for isolate identification and the Kirby-Bauer method for antibiotic susceptibility testing, alongside collecting clinical and demographic data from participants.
Results: Most fractures were open compound fractures (56.7%), all of which were mandibular fractures. For 60% of patients, open reduction internal fixation (ORIF) was the most frequently used surgical procedure. *Staphylococcus aureus* accounted for 27 (90%) of all isolates from surgical sites, with *Klebsiella pneumoniae* coming in second at 30%. Three instances (10%) had no bacterial growth. Amoxicillin, augmentin, aztreonam, cefotaxime, cefoxitin, ceftazidime, piperacillin, ceftriaxone, and doxycycline did not work at all against isolates of *S. aureus*.
Conclusion: According to the survey, individuals aged 20 to 24 represented 56.7% of cases, primarily due to gunshot wounds. The bacterium *S. aureus*, noted for its significant multidrug resistance, was the most commonly isolated pathogen. Vancomycin emerged as the most effective treatment for *Staphylococcus aureus* infections.
Keywords: Antibiotic pattern, bacterial causes, hardware removal, mandibular fracture, maxillofacial fractures, postoperative infections.

INTRODUCTION

Maxillofacial injuries account for between 7.4% and 8.7% of emergency medical care, making them one of the most frequent life-threatening crises in both industrialised and developing nations[1]. These injuries can outcome in serious, cosmetic, long-term functional, and psychological concerns since they impact the facial region's soft tissues as well as skeletal structures[2]. The maxillofacial region is the most vulnerable to fractures because of its prominent placement. The pattern and location of these fractures depend on the type of injury and the direction of trauma[3]. While maxillofacial skeleton fractures by themselves are rarely lethal, concurrent damage to other organs may complicate matters. Other significant diseases include neurological, orthopaedic, and ophthalmological damage frequently accompanies maxillofacial fractures[4]. Because these injuries are so close to important organs like the brain and cervical vertebrae, they are frequently linked to significant morbidity.

However, they can also result in loss of function, impairment, and even death[5]. The epidemiology and aetiologies of facial fractures diverge with demographic in terms of severity and cause[6]. Falls were the most frequently reported cause of craniofacial fractures in younger individuals, while RTA and assault have been found to be the main causes in adults. Understanding maxillofacial trauma makes it easier to assess how people behave in different countries and helps create effective injury management and prevention techniques.

Infections from surgical wounds can be deep (muscle and tissue), external (skin), or extend to the organ or site of the procedure. Regardless of whether the bacteria were previously on the patient's skin or oral mucous membrane or whether they were transferred to the patient from the hospital setting or from contact with infected people, surgical wound infections are commonly found and can develop within the first 30 days after surgery[7-9]. Recent research indicates that postoperative infections can occur years after surgery, and these infection rates go unreported for a number of reasons, such as not meeting national records requirements, missing patient follow-up, having difficulty accessing a prior surgical history, seeing a different surgeon, and more[10-12]. The CDC has divided SSIs into three categories: superficial infections, deep wound infections, and infections affecting organs or bodily compartments. The likelihood of an SSI is influenced by the level of contamination at the surgical site during the surgery. Wounds are categorised as clean, contaminated, unclean, or infected depending on the degree and frequency of contamination[13]. SSI epidemiology study presents challenges due to the heterogeneous nature of this surgical infection. The frequency varies significantly amongst surgeons, patients, institutions, and procedures[14]. The SSI can be changed by both foreign and internal bacteria. The majority of surgical site infections are caused by endogenous germs on the patient's skin at the time of the incision. Skin infections are more frequently caused by gram-positive bacteria like *S. aureus*. Microorganisms in the patient's body that are exposed during surgery are more likely to be the source of SSIs.

Pathogens differ depending on the surgical site; gastrointestinal tract surgery, for instance, raises the risk of SSI from Gram-negative gut bacteria[15]. The research literature recognises several related variables given the risk factors for SSI, but the studies are not repeatable. Despite this, a number of papers have frequently identified advanced age, male sex, and considerable blood loss as risk factors for SSI[16-19]. Postoperative, procedure-related (peri-operative), and patient-related (preoperative) are common categories for additional risk factors for SSI[19]. Surgical site infection (SSI) risk factors associated with patients can generally be categorised as either changeable or non-modifiable. Poor diabetes control, immunosuppressive drug use, obesity, tobacco use, and length of preoperative hospital stay are patient-related variable risk factors. Wound type, surgical site haircut, hypoxia, length of surgery, and hypothermia are risk factors associated with the procedure. Risk factors that can be changed or not, such age and gender, have been taken into consideration[20]. Despite earlier research on bacterial profiles, antibiotic sensitivity, and risk factors for UTI in postoperative patients at specialist hospitals in Sana'a, Yemen[21], as well as one study on general SSI, there is no information regarding SSI in craniofacial surgery in Yemen. Thus, the purpose of this investigation was to ascertain the frequency, distribution, and antibiotic susceptibility profiles of bacterial pathogens isolated from SSI linked to maxillofacial surgery postoperative wounds in a subset of hospitals in Sana'a City, Yemen.

MATERIALS AND METHODS

A comparative, serial clinical follow-up investigation was carried out. Patients who presented with trauma in the maxillofacial surgery department of the Military hospital between January 1, 2024, and December 31, 2024 (time for clinical works for the MD degree), were included in this study. Details were provided regarding age, sex, socioeconomic status, primary complaint, history of present illness, history of prior medical conditions, duration of injury, aetiology, and related injuries. In order to make a diagnosis, every patient in this study had a thorough clinical examination and radiological interpretation after data collection.

Data collection methods

An experienced MD student examined patients physically to determine whether a local infection was present based on one or more of the following criteria: pain, tenderness, local swelling, redness, warmth or purulent discharge, evidence of an abscess, or fever higher than 38°C in deep incisions.

Specimen collection

Patients who came in for a medical evaluation had wound swabs or aspirates taken aseptically from their surgery sites. This was carried out before applying an antiseptic solution to the wound. After that, specimens were transferred to the National Centre for Public Health Laboratories' Bacteriology Department for bacteriological examination in 5 ml Stewart transport media.

Bacterial isolation and identification

Samples were tested using established bacteriological procedures for swabs and aspirates[22]. The conventional streak plate method was used to inoculate the samples onto blood agar, Mannitol salt agar, and MacConkey agar (Oxoid). The plates were incubated for 24 to 48 hours at 37°C in an anaerobic environment.

Bacterial growth on medium was verified by colony morphology, pigment production, blood haemolysis (beta, alpha, and gamma haemolysis), biochemical tests (lactose, mannitol, glucose, and sucrose fermentation), and motility property testing. Bacteria growing on both blood agar and mannitol salt agar are considered Gram-positive because mannitol salt agar is a selective medium for *Staphylococcus*. A catalase test was then performed to distinguish *Streptococcus* from staphylococci; if the test produced negative results, streptococcal species were ruled out. Additionally, to differentiate *S. aureus* from other *Staphylococcus* species that test negative for coagulase, a coagulase enzyme test was performed. Microorganisms grown on MacConkey agar and blood agar are assumed to be Gram-negative bacteria since they are a selective medium for such germs. The lactose fermentation characteristics of the colonies on MacConkey agar were identified. Colonies that were colourless were lactose non-fermenters, whilst colonies that were pink were lactose fermenters. Gram-negative bacteria were further investigated for motility and characterisation using a range of biochemical assays, including indole, urea, Triple Sugar Iron agar (TSI), Simmon's Citrate agar, and Lysine Decarboxylase (LDC). Oxidase was employed to assess colonies that produced colour on blood agar and non-lactose fermenter on MacConkey agar in order to verify that *P. aeruginosa* is an oxidase-positive bacteria. Gram-negative bacteria were also tested for motility and discrimination using a range of biochemical techniques, including triglyceride iron agar (TSI), indole, urea, Simmon's Citrate agar, and Lysine Decarboxylase (LDC).

Antimicrobial susceptibility testing

The isolates' patterns of antibiotic susceptibility were investigated using the Kirby-Bauer diffusion technique on Mueller-Hilton agar (Oxoid). Four to five identically shaped bacterial colonies were suspended in five millilitres of nutritional broth. Following that, the turbidity of the solution was reduced to 0.5 McFarland, resulting in a colony count of around 10^7 or 10^8 colony-forming units per millilitre. A sterile swab was placed immediately in the centre of the Mueller-Hilton agar plate and then evenly dispersed to create confluent growth after being inserted into the solution and pushed against the tube's walls to remove any surplus. To test for *streptococci* susceptibility, 5% defibrinated sterile blood was aseptically added to Mueller-Hilton agar[22].

After the contaminated plates had dried for three to five minutes, the appropriate anti-microbial susceptibility discs were aseptically placed and gently pushed against the medium for complete surface contact using sterile forceps. To avoid the region of inhibition overlapping, the discs were spaced around 24 mm apart and 15 mm apart from the plate's edge. The plates were incubated aerobically at 37°C for 18 to 24 hours in incubator[23]. The diameter of each antibiotic's zone of inhibition was measured to the nearest millimetre using a digital calliper (Market lab, UK). According to Cheesbrough[22] and the Clinical Laboratory Standard Institute standards of 2015[23], the width of the inhibition zone of the tested bacteria surrounding the disc was measured to the closest millimetre and then categorised as sensitive and resistant. Amikacin (30 µg), clarithromycin (30 µg), amoxicillin-clavulanic acid (30 µg), ampicillin (10 µg), penicillin (30 µg), erythromycin (15 µg), ceftriaxone (30 µg), cefixime (30 µg), ceftazidime (30 µg), cefotaxime (30 µg), gentamicin (10 µg), ciprofloxacin (5 µg), norfloxacin (25 µg.

Data analysis

Epi Info version 6 (CDC, Atlanta, USA) was used to analyse the data. While the categorical variables were summarised using frequencies and proportions and displayed as tables, the continuous variable (age) was summarised using mean and standard deviation.

Ethical consideration

The Medical Ethics and Research Committee of the Military Hospital granted ethical permission for this project (No. 12 dated December 1, 2023). Every process complied with the review committee's ethical standards. Consent was also obtained from each participant, who was told that participation was entirely optional and that they might decline at any time for any reason.

RESULTS

The age distribution of maxillofacial fracture patients receiving device treatment at the Military Hospital is displayed in Table 1. The patient’s age ranged from 20 to 57 years, with a mean ± standard deviation of 29.9 ± 12.4 years. There was not a single instance of a female patient; all were male. The prevalence and aetiology of maxillofacial and face fractures are given in Table 2. Gunshot wounds accounted for 50% of all cases, with road accidents coming in second at 20%, bomb blasts at 16.7%, and pathological fractures at 13.3%.No cases of falls from height were recorded. There were 43.3% of closed simple fractures and 56.7% of open complicated fractures.

Table 1: Age distribution of maxillofacial fracture patients treated in the Military hospital (n=30).

Age group	N (%)
18 -24 years	12 (40)
25-29 years	9 (30)
≥30 years	9 (30)
Mean age	29.9 years
SD	12.4 years
Mode	20 years
Median	28 years
Min to Max	18 - 60 years
Total	30 (100)

The locations of our patients' maxillofacial fractures fractures were mandibular. Reconstructive plate counting accounted for 60% of the surgeries, miniplate counting for 30%, and titanium mesh for just three (10%). The clinical assessment of fracture patients is displayed in Table 3. 33.3% of cases had pain at the fracture site, 36.7% had fever, 3.3% had chills, 43.3% had night sweats, 46.7% had skin erythema, 70% had purulent discharge, 20% had discomfort at the fracture site, and 10% had movement at the fracture site.

Table 2: Causes and mode of occurrence of maxillofacial fractures in patients treated in the Military hospital (n=30).

Mode of injury	N (%)
Road traffic accidents	6 (20)
Fall from height	0 (0.0)
Gunshot	15 (50)
Bomb explosion	5 (16.7)
Pathological fractures	4 (13.3)
Total	30 (100)

The most prevalent surgical procedure was open reduction internal fixation (ORIF) alone in 60% of patients, followed by open reduction internal fixation with intermaxillary fixation (IMF) in 40%, and open reduction internal fixation with bone grafting in 0% of cases. The most common bacteria isolated from the surgical site was *S. aureus*, accounting for 27 (90%) of the total isolates, followed by *K. pneumoniae* at 30%, while 3 cases (10%) showed no bacterial growth.The antimicrobial susceptibility pattern of the isolated *S. aureus* (n=27) is displayed in Table 4. The *S. aureus* isolates were totally resistant to amoxicillin, aug-mentin, aztreonam, cefotaxime, cefoxitin, ceftaz-idime, piperacillin, ceftriaxone, and doxycycline. With a 100% sensitivity rate, vancomycin was the most effective drug against *S. aureus*. The next greatest sensitivity rate was 88.9% for teicoplanin, followed by 55.5% for tobramycin, 66.7% for gentamicin, and 55.5% for co-trimoxazole. *S. aureus's* sensitivity to several antibiotics ranged from 22.2% to 59.3%. Table 5 shows the antibiotic susceptibility pattern of the nine identified *K. pneumoniae*.

Table 3: Clinical examination of fracture patients treated in the Military hospital (n=30).

Symptoms	No (%)
Pain at site of fracture	10 (33.3)
Fever	11 (36.7)
Chills	1 (3.3)
Night sweating	13 (43.3)
Erythema	14 (46.7)
Purulent discharge	21 (70)
Tenderness	6 (20)
Motion at fracture site	3 (10)
Total	30 (100)

The *K. pneumoniae* isolates were completely resistant to amoxicillin, augmentin, cefotaxime, cefoxitin, ceftazidime, ceftriaxone, co-trimoxazole, and genta-micin. Amikacin and ciprofloxacin sensitivity rates for *K. pneumoniae* are 33.3%.

Table 4: Antimicrobial susceptibility pattern of the isolated *S. aureus* (n=27).

Antibiotics	Sensitive, N (%)	Resistant, N (%)
Amikacin	9/27 (33.3)	18/27 (66.7)
Amoxicillin	0/27 (0.0)	27/27 (100)
Augmentin	0/27 (0.0)	27/27 (100)
Aztreonam	0/27 (0.0)	27/27 (100)
Cefotaxime	0/27 (0.0)	27/27 (100)
Cefoxitin	0/27 (0.0)	27/27 (100)
Ceftazidime	0/27 (0.0)	27/27 (100)
Ceftriaxone	0/27 (0.0)	27/27 (100)
Ciprofloxacin	3/27 (11.1)	24/27 (88.9)
Co-trimoxazole	15/27 (55.5)	12/27 (44.4)
Doxycycline	0/27 (0.0)	27/27 (100)
Erythromycin	6/27 (22.2)	21/27 (77.7)
Gentamicin	18/27 (66.7)	9/27 (33.3)
Levoflxacin	16/27 (59.3)	11/27 (40.7)
Linezolid	15/27 (55.5)	12/27 (44.4)
Moxifloxacin	12/27 (44.4)	15/27 (55.5)
Piperacillin	0/27 (0.0)	27/27 (100)
Tetracycline	6/27 (22.2)	7/9 (77.7)
Vancomycin	27/27 (100)	0/27 (0.0)
Tobramycin	15/27 (55.5)	12/27 (44.4)
Clindamycin	6/27 (22.2)	21/27 (77.7)
Teicoplanin	24/27 (88.9)	3/27 (11.1)

DISCUSSION

The prevalence of maxillofacial injuries has increased in both urban and rural regions, and both industrialized and developing nations have seen a shift in this trend[24]. While interpersonal violence has been found to be the main cause of maxillofacial injuries in wealthy countries [25], RTA has been found to be the main cause in developing countries[26]. It is claimed that epidemio-logical evaluations are more specifically required for the implementation of prevention measures and the effectiveness of therapy. This is greater than the ratio of 4.6:1 observed in Bulgaria[27], in China[28], in Jordan, 3:1[29], and 2.1:1 in an Austrian study[30]. Furthermore, this ratio was higher than that found in a number of Saudi studies; in Jeddah, it was 4.4:1 in one study and 4.8:1[31] in another[32]. An 8:1 ratio was noted by Shanker *et al.*[33], and Motamedi *et al.*[34]. Cultural factors could be the cause of this discrepancy. On the other hand, compared to the Indian report, this ratio was smaller. The ratio was estimated to be 6:1 in Jeddah[35] and 10:1 in Abha City[32] in the southern region of Saudi Arabia. In the current study, gunshot wounds were the most common cause, accounting for 50% of all cases. Next in line were pathological fractures (13.3%), bomb blasts (16.7%) and traffic accidents (20%). No incidents of falls from a height were reported. The current study discovered that road traffic accidents were the second major cause of maxillofacial fractures, in contrast to previous findings in other studies by Brasileiro and Passeri[36]; Mijiti *et al.*[28], Motamedi *et al.*[34], and Saudi Arabia by Nwoku and Oluyadi[37], Abdullah *et al.*[38], Al-Masri[32] where the main cause was traffic accidents. Gunshots are seen as a serious public health concern in Yemen because to the ongoing conflict and the rising number of gun owners there. The main cause of traffic accidents in Yemen was shown to be driver mistake, mostly as a result of underage driving. Since alcohol and drugs are illegal in Yemen, they are not frequently the cause of traffic accidents.

Table 5: Antimicrobial susceptibility pattern of the isolated *K. pneumoniae* (n=9).

Antibiotics	Sensitive, N (%)	Resistant, N (%)
Amikacin	3/9 (33.3)	6/9 (66.7)
Amoxicillin	0/9 (0.0)	9/9 (100)
Augmentin	0/9 (0.0)	9/9 (100)
Cefotaxime	0/9 (0.0)	3/3 (100)
Cefoxitin	0/9 (0.0)	9/9 (100)
Ceftazidime	0/9 (0.0)	9/9 (100)
Ceftriaxone	0/9 (0.0)	9/9 (100)
Ciprofloxacin	3/9 (33.3)	6/9 (66.7)
Co-trimoxazole	0/9 (0.0)	9/9 (100)
Gentamicin	0/9 (0.0)	9/9 (100)

Human mistake and vehicle technical failures were the main causes of traffic accidents, which made for 20% of all road accident causes in the current study. Therefore, stringent enforcement of the legislation and national public awareness campaigns are necessary to reduce road accidents in Yemen.

The locations of maxillofacial fractures in patients who visited Military Hospital were determined in the current study; all of the fractures were mandibular. Our study's findings regarding the prevalence of mandibular fractures are comparable to those from other regions of the world[27,28,36], various Middle Eastern nations[34], and Saudi Arabia[32,38]. These results, however, are at odds with those from Australia[39], Germany[40], and Saudi Arabia[37], where the majority of patients had orbital fractures, midfacial fractures with orbital floor injuries, and midfacial fractures were significantly more common than mandibular fractures, respectively. The difference in the affected bone may be related to the different causes reported in different studies in which gunshot was the most cause in the current study.In line with the results of Haug *et al.*[6], the most frequently reported broken part of the maxillofacial bones in this study was the mandibular body fractures. The symphysis was the second most prevalent location for mandibular fractures after mandibular body fractures, according to another study by Mijiti *et al*.[28]. Condylar fractures and symphysis fractures were the most frequent locations of mandibular fractures, according to one study by Brasileiro and Passeri[36], while symphysis–parasymphysis fractures and condylar fractures were the most frequent locations, according to a study by Motamedi *et al*.[34]. This difference in the most affected location may be caused by the mechanism and direction of the impact at the time of the accident.

The majority of patients in the current study (60%) had open reduction internal fixation (ORIF). This is comparable to the findings of a study conducted in China by Meghetti*et al.*[28], which found that 62.4% of afflicted patients received ORIF treatment, and a study conducted in India[7], which found that 62.2% of patients received this treatment. 48% of the 1024 patients in Brazil that Brasileiro and Passeri[36] retrospectively examined received conservative treatment, whereas the remaining 48% received surgical treatment, mostly by ORIF. On the other hand, in a number of other investigations by Bataine[29] and Bakardjiev and Pichalova[27], closed reduction was the most frequently used treatment approach.

S. aureus was found to be the most frequently isolated species (90%) in this investigation. The findings are higher than those of studies conducted in Ethiopia, where the percentages of *S. aureus* were 33.3%[16] and 26.2%[18]. In Uganda, *K. pneumonia* was the most prevalent isolate, with a 50% rate[41]. This disparity in the distribution of bacterial species may be due to differences in prevalent hospital-acquired illnesses as well as policies and recommendations for infection prevention and management among countries and wound sites.

Amoxicillin, augmentin, aztreonam, cefotaxime, cefoxitin, ceftazidime, piperacillin, ceftriaxone, and doxycycline were all completely ineffective against the *S. aureus* isolates used in this study. Vancomycin was the most efficient antibiotic against *S. aureus*, with a 100% sensitivity rate. The next greatest sensitivity rates were 88.9% for teicoplanin, 55.5% for tobra-mycin, 66.7% for gentamicin, and 55.5% for co-trimoxazole. According to a study that was previously published in Yemen by Alhadi *et al*.[42], Al-Makdad *et al*.[21], and Ethiopia by Gelaw *et al*.[43], these antibiotics were found to be reasonably efficient in treating SSIs caused by *S. aureus*. Conversely, the Al Shami *et al.* investigation found that these medications were less effective[44]. It is possible that the increase in antibiotic resistance brought on by the irrational use of anti-infective medications, insufficient controls to prevent the spread of infections, variations in common hospital-acquired pathogens and the acquisition of organisms resistant to antibiotics are linked to both the duration of exposure to these microorganisms and the presence of risk factors.

Furthermore, the current study demonstrated that amoxicillin, augmentin, cefotaxime, cefoxitin, ceftazi-dime, ceftriaxone, co-trimoxazole, and genta-micin had no effect at all on the *K. pneumoniae* isolates. The sensitivity rates of *K. pneumoniae* to amikacin and ciprofloxacin are 33.3%. These results are almost completely different from those previously reported in Yemen[21,45-49], where the sensitivity rates for the aforementioned studies were given. The current study shows that the polyclonal antibiotics amoxicillin, augmentin, cefotaxime, cefoxitin, ceftazidime, ceftri-axone, co-trimoxazole, and gentamicin are all 100% ineffective against Gram-negative bacteria, particularly *K. pneumoniae*. Compared to previous research conducted in Yemen, this resistance rate was higher[45-49]. This might be because the development and spread of resistance are mostly caused by the experimental treatment of isolates, the haphazard and frequent use of these antibiotics by inexperienced practitioners, and the absence of antibiotic usage standards[21,44,50].

Limitations of the study

The small sample size and short-term follow-up were the study's primary limitations.

CONCLUSION

According to the survey, people between the ages of 18 and 24 accounted for the majority of instances (56.7%). The most frequent cause was gunshot wounds. *S. aureus*, which has a very high prevalence of multidrug resistance, was the most frequently isolated bacterium. The most effective medication for treating *S. aureus* infections was discovered to be vancomycin.

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AUTHOR'S CONTRIBUTIONS

Al-Sabri HN: formal analysis, conceptualization, data organization, and clinical and laboratory examinations to obtain a board's degree in Oral and Maxillofacial Surgery. **Al-Rahbi LM:** conceptualization, data organization, supervision. **Al-Ashwal AA:** conceptualization, data organization, supervision. **Al-Shamahy HA:** critical review. Final manuscript was checked and approved by both authors.

DATA AVAILABILITY

The empirical data used to support the study's conclusions are available upon request from the corresponding author.

CONFLICT OF INTEREST

Regarding this project, there are no conflicts of interest.

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