



RESEARCH ARTICLE

TREATMENT OF COMMINUTED MANDIBULAR FRACTURE WITH CLOSED REDUCTION AND MANDIBULAR FIXATION VERSUS OPEN REDUCTION AND INTERNAL FIXATION

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Abstract

Background and aims: Injuries from firearms remain a serious public health concern, contributing significantly to our society's morbidity, mortality, and costs. Securing an airway, controlling bleeding, determining other injuries, and conclusively repairing the traumatic facial abnormalities are the four primary phases in the care of patients with gunshot wounds to the face. This study aimed to compare the effects of two treatment approaches for mandibular gunshot injuries: closed reduction and maxillomandibular fixation (MMF) against open reduction and internal fixation.

Methods: Between 2020 and 2023, mandibular fractures were found in two equal groups at the Military Hospital in Sana'a, Yemen, where the Department of Oral and Maxillofacial Surgery conducted the study. Twenty patients in group A received treatment by closed reduction and maxillo-mandibular fixation, and another twenty patients in group B received treatment by open reduction and internal fixation. Then complications following surgery were studied. Every patient had made a follow-up call between the second and eighth weeks; following the surgery, both groups' cases of postoperative infection, malocclusion, non-union or malunion of fracture fragments, facial asymmetry, exposed plates, and bone resorption were recorded and assessed radiographically and clinically.

Results: The study analyzed patients with mandible fractures, focusing on G.S.I. and bomb explosions. Most injuries occurred in the body, with parasymphysis being the most common site. Bone exposure was prevalent in 95% of patients. After a two-week follow-up, the ORIF treatment method was associated with more post-operative complications than the CR-MMF treatment method. Wound contraction was more common in the ORIF group (22.5%), followed by bone loss (15%). Plate exposure, nonunion, and malunion were more prevalent in the ORIF group.

Conclusions: In comparison to open reduction with internal fixation, it was determined that closed reduction is the most efficient and dependable management strategy for treating comminuted fractures of the mandible brought on by gunshot injuries. It also has a lower rate of complications.

Keywords: Close reduction, comminute, gunshot, internal fixation, mandibular fracture, open reduction, Yemen.

INTRODUCTION

At 40.4%, gunshot wounds are known to be the most common cause of maxillofacial fractures, with explosive injuries coming in second at 31.6%¹. It is commonly known that gunshot wounds to the face frequently result in considerable morbidity and fatality². Nevertheless, because of the possibility of

major postoperative complications such as infection, malocclusion, facial deformity, non-union of the bone, and even bone abnormalities, handling cranio-maxillofacial fractures is a significant problem for the majority of surgeons³. Mandibular fractures are the most common type of facial bone fracture. Bony injuries related to gunshot wounds to the face usually occur in the following order: mandible, maxilla, and

zygomatic bone¹. Simple comminuted mandibular fractures entail the presence of multiple fracture lines that result in numerous small pieces within the same mandibular region (ramus, angle, body, or symphysis/parasymphysal); conversely, extensive comminuted mandibular fractures are characterized by comminuted fractures that involve multiple sites beyond a single region⁴.

Serious injuries in the maxillofacial region include comminuted mandibular fractures. The mandibular occlusion and the look of the lower facial regions are affected by these fractures, posing a challenge to maxillofacial surgeons. Accurate anatomical reduction and stable fixation of the bone pieces are essential for treating these fractures and preventing postoperative sequelae such as infection, malocclusion, and altered facial appearance⁵. Patients with facial gunshot wounds need to be initially treated using the advanced trauma life support (ATLS) algorithm⁶. Many techniques have been used to treat mandibular comminuted fractures, including closed reduction, internal wire fixation, external pin fixation, and, more recently, open reduction and internal stable fixation with plates and/or screws⁷. In the past, comminuted mandibular fractures caused by gunshot wounds were managed through closed reduction; however, authors have not presented evidence supporting the superiority of rigid fixation methods. It was believed that these techniques led to increased complications due to devitalization of bone segments as a result of periosteum and blood supply stripping, potentially contributing to the elevated complication rates observed by certain surgeons⁷. For comminuted mandibular fractures from gunshot wounds, modern treatment modalities include open reduction and internal fixation with miniplates and reconstruction plates. The concepts of classical maxillofacial surgery, which support closed treatment of comminuted fractures to preserve blood flow in the fragments, run counter to the present approach. The outcomes of open reduction and internal fixation in the past were depressing, as many occurrences of infection resulted in significant bone loss and related morbidity. Located in the core of Sana'a, Yemen's downtown, the Military Hospital is a vital trauma centre that serves a wide variety of patients in need of medical care. Located on its grounds is the Department of Oral and Maxillofacial Surgery, which is well-known throughout the country for having state-of-the-art tools and resources that are devoted to treating a wide range of oral and maxillofacial conditions. For the treatment of maxillofacial injuries, patients of all ages and from all across the nation are regularly referred to this prestigious hospital. Under painstaking attention to detail, this study investigated the relative merits of closed versus open reduction techniques for the treatment of comminuted mandibular fractures resulting from gunshot wounds. The final results of this study, which underwent a thorough review of outcomes and data analysis, are expected to provide crucial insights into the best ways to manage comminuted mandibular fractures resulting from gunshot injuries.

METHODS

Study design: A comparative, serial clinical follow-up study.

Study population: All patients attending a military hospital between the first of January 2020 and the end of December 2023 (Time allowed for clinical work for the Master's degree).

Sample size: A sample size of 40 patients, divided into 2 groups, group A, in which they were treated by close reduction with maxillo-mandibular fixation, counting 20 patients. Group B; treated by open reduction and internal fixation (reconstruction plates or/and miniplates counting 20 patients).

Inclusion criteria: The study included patients of age > 17 years, male, with whom a comminuted fractures in the mandible by gunshot.

Exclusion criteria: Patients below 17 years of age with a known systemic or bone disease, patients with mandibular bone defect fractures, or patients with an old fracture.

Data collection procedure: Upon meeting the predefined criteria for inclusion, all patients were promptly admitted to the emergency department located within the confines of the military hospital situated in Yemen, where a thorough explanation of the study protocol was meticulously provided to each individual, following which written informed consent was duly obtained from every patient. Relevant demographic information including details such as age, medical background, behavioural habits, as well as contact details are carefully documented using a form designed specifically for this purpose. The process of diagnosing the patients commenced with a comprehensive collection of their medical history, a meticulous clinical examination, and a detailed radiological assessment, involving the acquisition of a standard radiograph CT scan coupled with 3D reconstruction, encompassing both axial and coronal views, conducted as a preoperative measure. Additionally, laboratory investigations were diligently carried out for every patient included in the study. Subsequent to the initial assessments, the cohort of patients was systematically categorized into two distinct groups denoted as "A" and "B.". Following admission to the healthcare facility, the patients underwent a period of fasting, abstaining from oral intake for duration of 6 hours preceding the scheduled surgical procedure. On the day of the operation, explicit consent for general anesthesia was obtained from each patient by healthcare personnel, and meticulous adherence to the universal protocol for surgical draping and preparation was meticulously observed prior to the commencement of the surgical intervention, ensuring that all patients were adequately primed for the administration of general anesthesia. Standardized protocols for wound management and closure were diligently followed, involving the meticulous decontamination of intraoral and extraoral regions through the application of iodine and normal saline solution.

Local anesthesia, comprising lidocaine infused with 2% adrenaline at a ratio of 1:100,000, was judiciously

administered in the vicinity of the fracture site, following which an incision was meticulously executed utilizing a sterile surgical carbon steel blade #15 to gain access to the area of fracture. Subsequent to the successful reduction of the fracture utilizing specialized instruments, the fixation of the affected region was meticulously achieved through the application of either IMF or ORIF techniques. Post-procedural decontamination was diligently carried out via the irrigation of the wound with iodine and normal saline, culminating in the closure of the incision in a dual-layer fashion utilizing sterile surgical sutures, namely Vicryl 3-0 and Prolene 4-0. Furthermore, the attendant of the patient was duly instructed to ensure the continuation of fasting for an additional 6-hour period post-operation. For group A, the patients were provided with arch bars made of 26 or 24 gauge pre-stretched stainless steel wires with an approximate diameter of 0.4 or 0.5 mm. The Maxillo-mandibular Fixation (MMF) technique was implemented by inserting a 24 or 26-gauge straight wire between the hocks of the upper and lower arch to achieve immobilization, which was maintained for a duration of six weeks. Medication regimens for group A included the administration of Augmentin 1.2 mg vial every 8 hours intravenously, metronidazole 500 mg/100 ml every 8 hours through infusion, as well as intramuscular analgesic diclofenac sodium 75 mg every 8 hrs and injection dexamethasone 8 mg every 8 hours for a short period.

In contrast, for group B, a decision was made regarding the retention of the tooth in alignment with the fracture based on whether it contributed to facilitating the reduction of the fracture by being associated with a substantial bony fragment. If the tooth was non-vital, had a root fracture, was loose, or hindered the reduction process, it was extracted. Temporary intraoperative inter-maxillary fixation was applied in Group B by the maxillofacial team. The Maxillo-mandibular Fixation (MMF) was released subsequent to the successful reduction and fixation of the fracture using plates and screws. Similar to group A, patients in group B received injections of Augmentin 1.2 mg intravenously every 8 hours, metronidazole 500 mg/100 ml every 8 hours through infusion, diclofenac sodium 75 mg intramuscularly every 8 hours, and dexamethasone 8 mg via injection every 8 hours. Postoperatively, dietary recommendations diverged between the two groups, with patients in group B advised to adhere to a soft diet while those in group A were instructed to follow a liquid diet. Additionally, stringent oral hygiene protocols were emphasized for all patients. Subsequently, all patients from both groups

were discharged from the hospital once their condition was deemed stable.

Follow-up appointments were scheduled for each patient at the 2nd, 4th, 6th, and 8th weeks postoperatively. During these follow-up visits, assessments were conducted to monitor for postoperative complications such as infections, malocclusion, non-union or malunion of fracture fragments, facial asymmetry, exposure of plates, and bone loss due to parafunctional movements. These evaluations were carried out during the 2-month follow-up period.

Statistical Analysis: Data analyzed by using statistical software SPSS version 20 (SPSS Inc., Chicago, IL, USA). Descriptive analyses: proportions, percentages, and frequency distribution were performed.

RESULTS

Most of our patients were under 31 years old. The most common etiology for mandible fractures was G.S.I. counting 85% of the total, while bomb explosions counted only 15% of the total. The most sites of injuries were in the body, counting 80% of the total patients, followed by parasymphysis, counting 55% of the total patients, while 35% of the patients had symphysis injuries, and only 15% had injuries in the ramus and 25% in the angle site. The bone exposure counted in 95% of total patients included in this study and only 5% had no bone exposure. All patients were communicating with the oral cavity (100%) of the total patients.

Table 1: The distribution of patients with mandible fractures caused by gunshot injury (G.S.I.).

Age	N (%)
Less than 21 years	17 (42.5)
21 - 30 years	19 (47.5)
31 - 40 years	3 (7.5)
41 years and more	1 (2.5)
Total	40 (100)

All patients under taking radiographic evidences by CT. Scan and panorama. After a two-week follow-up, the ORIF treatment method was found to be associated with more post-operative complications than the CR-MMF treatment method. Specifically, wound dehescence occurred in 12.5% of ORIF patients compared to 5% in CR-MMF patients, facial asymmetry occurred in 7.5% of ORIF patients compared to 2.5% in CR-MMF patients, malocclusion occurred in 0.0% of CR-MMF patients compared to 7.5% ORIF treatment group, and infection occurred in 2.5% of CR-MMF patients versus 10% in the ORIF treatment group.

Table 2: Distribution of causes of mandibular fractures and according to treatment methods for groups A, B, and the total groups.

Etiology	Closed	Open	Total
	Reduction (A)	Reduction (B)	
	N (%)	N (%)	N (%)
G.S.I	18 (45)	16 (40)	34 (85)
Bomb explosion	2 (5)	4 (10)	6 (15)
Total	20 (50)	20 (50)	40 (100)

Table 3: Distribution of injury sites for patients of mandibular fractures treated by closed reduction and open reduction and for the total.

Site of Injury	Closed Reduction (A)		Open Reduction (A)		Total	
	Yes N (%)	No N (%)	Yes N (%)	No N (%)	Yes N (%)	No N (%)
Ramus	3 (7.5)	17 (42.5)	3 (7.5)	17 (42.5)	6 (15.0)	34 (85.0)
Angle	3 (7.5)	17 (42.5)	7 (17.5)	13 (32.5)	10 (25.0)	30 (75.0)
Body	17 (42.5)	3 (7.5)	15 (37.5)	5 (12.5)	32 (80.0)	8 (20.0)
Parasymphysis	11 (7.5)	9 (22.5)	11 (27.5)	9 (22.5)	22 (55.0)	18 (45.0)
Symphysis	6 (15.0)	14 (35.0)	8 (20.0)	12 (30.0)	14 (35.0)	26 (65.0)

Table 8 shows the outcome of the post-operative complication following an 8-week follow-up. Wound contraction accounted for 32.5% of all complications, with a higher frequency in the ORIF group (22.5%) compared to the CR-MMF group (10%). Bone loss accounted for 15% of all post-operative complications, with all cases falling into the ORIF group versus 0.0% in the CR-MMF ($p=0.008$). Additional issues included plate exposure, non-union, and malunion, which were more prevalent in the ORIF group.

DISCUSSION

More than 85% of our patients were younger than 31. In line with earlier research by Ellis *et al.*⁷, Newlands *et al.*⁸, Hussain *et al.*⁹, Hollier *et al.*¹⁰, and Muddassar *et*

*al.*², the second and third decades made up the majority of the study's participants. All of the patients in the current study who presented with mandibular gunshot injuries were men. Other studies like Sharaf Aldin *et al.*¹, Ellis *et al.*⁷, Newlands *et al.*⁸, Hussain *et al.*⁹, and Finn *et al.*¹¹, are consistent with this. This outcome can be explained by the fact that, as a result of the ongoing war in Yemen and political stability, there is a generalized increased tendency for males to sustain firearm injuries nationwide, where males are predominantly indicated as the war first victims attending our centre in the military hospital. Additionally, because men are more likely to participate in combat-related activities, a greater percentage of casualties in war circumstances are often men.

Table 4: The rate of bone exposure among patients of mandibular fractures treated by closed reduction and open reduction and for the total.

Bone exposure	Closed Reduction	Open Reduction	Total
	group A N (%)	group B N (%)	
Yes	19 (47.5)	19 (47.5)	38 (95)
No	1 (2.5)	1 (2.5)	2 (5)
Total	20 (50)	20 (50)	40 (100)

Table 5: The rate of communication with the oral cavity among patients of mandibular fractures treated by closed reduction and open reduction and for the total.

Communication with oral cavity	Closed Reduction-A	Open Reduction-B	Total
	N (%)	N (%)	
Yes	20 (50)	20 (50)	40 (100)
No	0 (0.0)	0 (0.0)	0 (0.0)
Total	20 (50)	20 (50)	40 (100)

The mandibular body region accounted for 53.3% of all fractures observed in our study, with the symphysis-parasymphysis (17.8%), angle (14.4%), and ramus region (14.4%) following closely behind. This result is in line with some earlier research. For instance, the most frequent fracture site in the jaw, according to Newlands *et al.*⁸, is the mandibular body (38.8%), which is followed by the angle and the anterior area. Other studies have shown similar results, suggesting that the mandibular body's vast surface area may be a factor in its frequent occurrence in fractures. The evaluation of postoperative complications such as wound dehiscence, facial asymmetry, malocclusion, infection, plate exposure, nonunion, malunion, wound contraction, and bone loss was the primary focus of the analysis in the current research conducted. One of the major challenges encountered by scholars in reviewing the existing literature pertains to the difficulty in

standardizing the tools used to assess these complications and establish their prevalence across different studies⁷⁻¹⁰. In current investigation, the primary complication observed, wound rupture, and occurred in 7 patients who had infection throughout the entire observation period. Of these 7 patients, 12.5% belonged to the ORIF group, while 5.0% belonged to the CR-MMF group. The decreased vascularity resulting from the elevated periosteum not only increases the risk of wound rupture, but also increases the possibility of bacterial and fungal contamination of the surgical site. Prolonged periosteum rupture can also weaken the body's resistance to infection^{1,10-12}.

The subsequent complication identified in our research was infection, with five patients developing infections over the course of the study. Among these cases, 10% were associated with the ORIF group, while 2.5% were linked to the CR-MMF group.

Table 6: Radiographic evidence among patients of mandibular fractures treated by closed reduction and open reduction and for the total.

Radiographic evidence	Closed Reduction-A	Open Reduction-B	Total
	N (%)	N (%)	N (%)
CT. Scan and Panorama	20 (50)	20 (50)	40 (100)
Total	20 (50)	20 (50)	40 (100)

Table 7: Post-operative complications after 2 weeks of follow up for patients of mandibular fractures treated by closed reduction or open reduction and for the total.

Post-Operative complication Follow up after 2 week		Treatment Method		Total	p
		CR-MMF (A)	ORIF (B)		
		N (%)	N (%)		
Wound dehiscence	Yes	2 (5)	5 (12.5)	7 (17.5)	0.212
	No	18 (45)	15 (37.5)	33 (82.5)	
Facial asymmetry	Yes	1 (2.5)	3 (7.5)	4 (10)	0.292
	No	19 (47.5)	17 (42.5)	36 (90)	
Malocclusion	Yes	0 (0.0)	3 (7.5)	3 (7.5)	0.072
	No	20 (50)	17 (42.5)	37 (92.5)	
Infection	Yes	1 (2.5)	4 (10)	5 (12.5)	0.151
	No	19 (47.5)	16 (40)	35 (87)	

$p < 0.05$ is statistically significant

This particular discovery in our study aligns with prior research findings that have highlighted a higher incidence of infections in cases involving ORIF procedures. For instance, Channar *et al.*¹³, conducted a prospective study focusing on the outcomes of ORIF and CR-MMF, reporting infection rates of 16.6% and 10% for ORIF and CR-MMF, respectively. Similarly, Neupert and Boyd¹⁴ conducted a retrospective analysis of low-velocity gunshot wounds to the mandible, revealing a 27% infection rate following ORIF procedures, which corroborates our study's findings regarding the elevated risk of infections associated with ORIF treatments¹⁴. The third complication observed in our research pertained to facial asymmetry, where a total of 4 patients exhibited this issue throughout the complete follow-up period. Among these 4 patients, three individuals (constituting 7.5%) were affiliated with the Open Reduction Internal Fixation (ORIF) group, while one patient (representing 2.5%) belonged to the Closed Reduction with Maxillo-mandibular Fixation (CR-MMF) group. This particular discovery within our study diverges from certain prior research endeavors that have indicated a higher prevalence of facial asymmetry associated with ORIF procedures. For instance, studies conducted by Rana *et al.*¹², and

Finn¹¹ highlighted that closed reduction methods were more likely to lead to postoperative facial deformities compared to open reduction internal fixation techniques. These aforementioned studies by Rana *et al.*¹², and Finn¹¹ specifically focused on patients with comminuted mandibular fractures, with or without accompanying bone defects; however, it is noteworthy to mention that our research did not include any individuals presenting with bone defects. The fourth complication identified in our investigation pertained to malocclusions, which were detected in a total of three cases. Among these instances, three cases (comprising 7.5%) of malocclusions were observed in the ORIF group, whereas no cases (0%) were reported in the CR-MMF group. Our research outcomes indicated that three cases of malocclusions were evident in patients who underwent ORIF procedures. It was apparent from our findings that open reduction and internal fixation methods were more likely to result in malocclusions compared to the closed reduction approach, a trend that has also been documented in prior studies. For instance, a study by Baumash *et al.*¹⁵, noted the absence of occlusal complications in cases treated with closed reduction, attributing this outcome to the specific number of fractures addressed.

Table 8: Post-operative complications after 8 weeks of follow up for patients of mandibular fractures treated by closed reduction or open reduction and for the total.

Post-operative complication Follow up after 8 week		Treatment methods		Total	p
		CR-MMF (Group A)	ORIF (Group B)		
		N (%)	N (%)		
Plate exposure	Yes	0 (0.0)	3 (7.5)	3 (7.5)	0.072
	No	20 (50)	17 (42.5)	37 (92.5)	
Non union	Yes	0 (0.0)	3 (7.5)	3 (7.5)	0.072
	No	20 (50)	17 (42.5)	37 (92.5)	
Malunion	Yes	1 (2.5)	0 (0.0)	1 (2.5)	0.311
	No	19 (47.5)	20 (50)	39 (97.5)	
Wound contraction	Yes	4 (10)	9 (22.5)	13 (32.5)	0.091
	No	16 (40)	11 (27.5)	27 (67.5)	
Bone loss	Yes	0 (0.0)	6 (15.0)	6 (15)	0.008*
	No	20 (50)	14 (35)	34 (85)	

* $p < 0.05$ is statistically significant.

Interestingly, only 10% of patients subjected to open reduction and internal fixation procedures developed malocclusions, indicating a disparity in the occurrence of this particular complication based on the treatment method utilized¹⁵. This finding in our study is in line with several previous research studies that have documented a higher prevalence of malocclusion associated with open reduction and internal fixation (ORIF), as demonstrated by Okoturu *et al.*¹⁶.

In their study involving 30 patients who underwent osteosynthesis, malocclusion was reported as the most common complication, affecting 23.3% of the cases. Our study findings align with this trend; however, we observed a lower rate of malocclusion (10%). Moreover, our results are consistent with other research studies, such as the ones conducted by Ellis *et al.*⁷, and Smith and Johnson *et al.*¹⁷, where a malocclusion rate of 4.1% was reported in the ORIF group.

The occurrence of non-union, one of the five complications examined in our study, was identified in three cases. Specifically, there were three cases (7.5%) of non-union in the ORIF group and none in the CR-MMF group. In our study, four cases of infection eventually led to non-union, with three cases originating from the ORIF group and none from the CR-MMF group. Infections can create a hypoxic environment, potentially resulting in fibrous unions without proper bone formation. Previous literature has highlighted a strong association between infection and non-union, with Mathog *et al.*¹⁸, reporting that 17 out of 25 non-union cases were linked to infections. This finding was further supported by Malanchuk and Kopchak¹⁹, who found that 55% of 195 infected mandible cases developed non-union as a secondary complication of infection.

Among the six complications analyzed in our study, malunion was detected in one case. Specifically, there was one case (2.5%) of malunion in the CR-MMF group and none in the ORIF group. Malunion was more common in the closed reduction group, a finding that is consistent with previous studies reporting a higher incidence of malunion associated with closed reduction procedures. Examples of such studies include those by Ellis and Muniz⁷, all of which have documented a higher prevalence of malunion in closed reduction with maxillomandibular fixation (MMF) or external pin fixation compared to ORIF.

The occurrence of plate exposure, one of the seven complications evaluated in our study, was identified in 3 cases (7.5%) in the open reduction group, a situation that cannot be directly compared with the closed reduction group. The process of adapting a reconstruction plate requires both skill and time, and achieving a perfect contour is not always feasible. These challenges may contribute to plate exposure. Factors such as infection at the surgical site and inadequate soft tissue coverage also play a significant role in this complication^{7,16}. In our study, two patients experienced plate exposure, a finding that cannot be directly compared with the closed reduction group. Ellis *et al.*⁷, in a retrospective study, highlighted that exposed plates are a rare complication often attributed to inadequate adaptation of reconstruction plates.

Additionally, Newlands *et al.*⁸, reported that plate exposure can occur due to infections at the hardware site or due to loose reconstruction plates. In our study, closed reduction showed significantly better outcomes and fewer complications compared to open reduction with internal fixation in terms of complications. Similarly, Channar *et al.*¹³.

Limitations of the study

The main limitation of this study was not including long-term follow-up.

CONCLUSIONS

In comparison to open reduction internal fixation, it was determined that closed reduction is the most dependable and efficient management method for treating mandibular comminuted fractures, with extremely low rates of early and late problems.

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AUTHOR'S CONTRIBUTIONS

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

DATA AVAILABILITY

The accompanying author can provide the empirical data that were utilized to support the study's conclusions upon request.

CONFLICT OF INTEREST

There are no conflicts of interest in regard to this project.

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