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Research Article

Treatment of comminuted mandibular fracture resulting from gun injury using closed reduction and mandibular fixation versus open reduction and internal fixation: a comparative study in the Military hospital in Sana'a, Yemen

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Abstract

Background and aims: Firearm injuries continue to be a major public health problem, contributing significant morbidity, mortality, and expense to our society. There are four main steps in the management of patients with gunshot wounds to the face: securing an airway, controlling hemorrhage, identifying other injuries, and definitive repair of the traumatic facial deformities. The objective of this study was to determine the outcome of two treatment options: open reduction and internal fixation versus closed reduction and maxillomandibular fixation (MMF) in the treatment of gunshot injuries to the mandible.

Materials & 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 parasymphsis 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.

Conclusion: 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.

Key words: Close reduction; Comminute; Gun shut; 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 fatality [2]. 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 surgeons [3]. 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 bone [1]. 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/pparasymphyseal); conversely, extensive comminuted mandibular fractures are characterized by comminuted fractures that involve multiple sites beyond a single region [4].

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 appearance [5]. Patients with facial gunshot wounds need to be initially treated using the advanced trauma life support (ATLS) algorithm [6]. 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 screws [7]. 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 surgeons [7]. 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 center 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.

Material And 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.

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 fracture 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, behavioral 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 a 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 Prolyne 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 hours 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.

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**

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

Etiology	Closed Reduction (A)		Open Reduction (B)		Total	
	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 2: Distribution of causes of mandibular fractures and according to treatment methods for groups A, B, and the total groups.

Site of Injury	Closed Reduction (A)				Open Reduction (A)				Total			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	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
Parasymphsis	11	27.5	9	22.5	11	27.5	9	22.5	22	55.0	18	45.0
Symphsis	6	15.0	14	35.0	8	20.0	12	30.0	14	35.0	26	65.0

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

Bone exposure	Closed Reduction group A		Open Reduction group B		Total	
	N	%	N	%	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 4: The rate of bone exposure 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	%	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**

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.

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

Post-Operative complication Follow up after 2 week		Treatment Method		Total	*p*
		CR-MMF (A) N (%)	ORIF (B) 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.

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

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 parasymphsis, counting 55% of the total patients, while 35% of the patients had symphsis 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. 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 dehesence occurred in 12.5% of ORIF patients compared to 5% in CR-MMF patients, facial asymatry 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 8

Post-Operative complication Follow up after 8 week		Treatment methods		Total N (%)	*p*
		CR-MMF (Group A) N (%)	ORIF (Group B) 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.

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

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, nonunion, and malunion, which were more prevalent in the ORIF group.

Discussion

Most of our patients were under 31 years old (more than 85%). The second and third decades constituted the major group in our study, consistent with previous studies by Ellis *et al.* [7], Newlands *et al.* [8], Hussain *et al*. [9], Hollier *et al.* [10] and Muddassar *et al*. [2]. In the current study, all patients presenting with gunshot injuries to the mandible were male. This aligns with other studies such as Sharaf Aldin *et al*. [1], Ellis *et al.* [7], Newlands *et al.* [8], Hussain *et al.* [9], and Finn *et al.* [11]. This result can be explained by the fact the fact that there is a general increased predilection for males to be victims of firearm injuries throughout the country due to the ongoing war in Yemen and political stability, where males are predominantly indicated as the war first victims attending our center in the military hospital. Also, in conflict situations, a larger proportion of casualties are often male due to their higher involvement in combat-related activities.

The most common site of fracture noted in our study was the mandibular body region (53.3%), followed by the symphysis-parasymphysis (17.8%), angle (14.4%), and ramus region (14.4%). This finding is consistent with some previous studies. For example, Newlands *et al.* [8] reported the mandibular body (38.8%) as the most common fracture site in the mandible, followed by the angle and then the anterior region. Similar findings have been reflected in other studies, where the large surface area of the mandibular body may contribute to its common 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 studies [7–10]. In our investigation, the primary complication observed, wound rupture, 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. 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 Boyd [14] 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 treatments [14]. 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 Finn [11] 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 Finn [11] 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 Baurmash *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. 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 utilized [15]. 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 Kopchak [19], 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 Muniz [7], 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 those 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 lose reconstruction plates. In our study, close reduction showed significantly better outcomes and fewer complications compared to open reduction with internal fixation in terms of complications. Similarly, Channar *et al*. [13].

Conclusion

It was concluded that closed reduction is the most effective and reliable management technique with very low rates of early and late complications for the treatment of comminuted fractures of the mandible as compared to open reduction internal fixation.

Limitations Of the Study

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

Data Availability

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

A Dispute of Interest

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

Author's Contributions

Dr. Mohammed Ali Mohammed Fathael Gamel: Formal analysis, conceptualization, data organization, and clinical and laboratory examinations to obtain a master's degree in Oral and Maxillofacial Surgery. All other authors supervised the work, reviewed the article, and approved the final version.

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