Management of Maxillofacial Gunshot Wounds: A Retrospective Study

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Introduction: Management of maxillofacial gunshot wounds (MGSWs) has long been challenging and a multidisciplinary approach in planning and reconstructing of MGSWs should be followed. The objective of this study was to retrospectively assess and present gunshot wound cases in a hospital in Iran. **Materials and Methods:** Fourteen MGSW at Departments of Oral and Maxillofacial Surgery at Jundishapur and Shahid Sadoughi Universities of Medical Sciences from 2011 to 2015 were retrospectively reviewed. Data was analyzed using SPSS version 16.0. Data was presented in the form of descriptive statistics: mean and standard deviation for all quantitative variables and frequency and percentages were presented for qualitative variables like gender, entry site of projectile, etc. **Results:** Age ranged from 18 to 42 years with mean of 27.34 years. There were 12 (85.7%) male and 2 (14.3%) female cases. From them, Ten (71.5%) patients required airway management. Mandible was the most frequent involved site (*i.e*, in 11 (78.5 %) patients), while midface was involved in 3 (21.5%) patients. Suicide was the main cause of gunshot (*i.e*, in 8 (57.1%) patients). Free fibular flap was applied in 4 (28.5%) patients, while 8 (57.1%) patients were managed with regional and distant flaps in combination with reduction internal fixation. The most common type of treatment was two stage delayed reconstruction (35.7%). Most of the patients (*i.e*, in 12 (85.7%) patients) had complications which trismus and infection were the most frequent complication being reported. **Conclusion:** This study shows that early management of MGSWs with local flaps results in better psychosocial profile, aesthetics, reduced hospital stay and faster functional rehabilitation

Keywords: Wound; Gunshot; Reconstruction

Introduction

Management of maxillofacial gunshot wounds (MGSWs) has long been challenging for the maxillofacial care professionals as they bear a lot of patient morbidity (1, 2). Inordinate attention has been given in the past to wound classification based merely on the projectile's velocity (1). These wounds used to be classified as penetrating, perforating and avulsive. Most recently, other classifications have been recommended to address more management and prognostic concerns. Management of MGSWs has been evolving through ages from conservative delayed operative repair to early aggressive single stage approach (2). Penetrating and perforating wounds, mainly resulting from low velocity projectiles, are managed in the same way as blunt facial trauma, ranging from closed reduction to open reduction and internal fixation with minimal debridment and primary closure (2, 3). Management of avulsive wounds resulting from high velocity projectiles has been controversial involving early and delayed reconstruction as it is complicated by tissue necrosis (2, 4). A multidisciplinary approach in planning and reconstructing MGSWs should be followed (5). The objective of this study was to determine the pattern and presentation (site of injury, airway, and associated injuries), implications for evaluation and management of the patients with avulsive MGSWs.

Materials and Methods

The study design was reviewed and approved by our local institutional review board. The guidelines of Helsinki declaration were followed in the present study. This retrospective series included MGSW patients referred to Department of Oral and Maxillofacial Surgery at Jundishapur and Shahid Sadoughi universities of Medical Sciences, from October 2011 to December 2015. Patients were managed initially in the field of injury with normalization of vital signs and then they were transferred to our center for definitive management. The maxillofacial anatomy was considered from supraorbital margin to the chin inferiorly and the area anterior to the external auditory meatus. The entry site of projectile was further subdivided into two anatomic subsites *i.e.* mandible-(lower face) and midface. MGSWs of the upper third of the

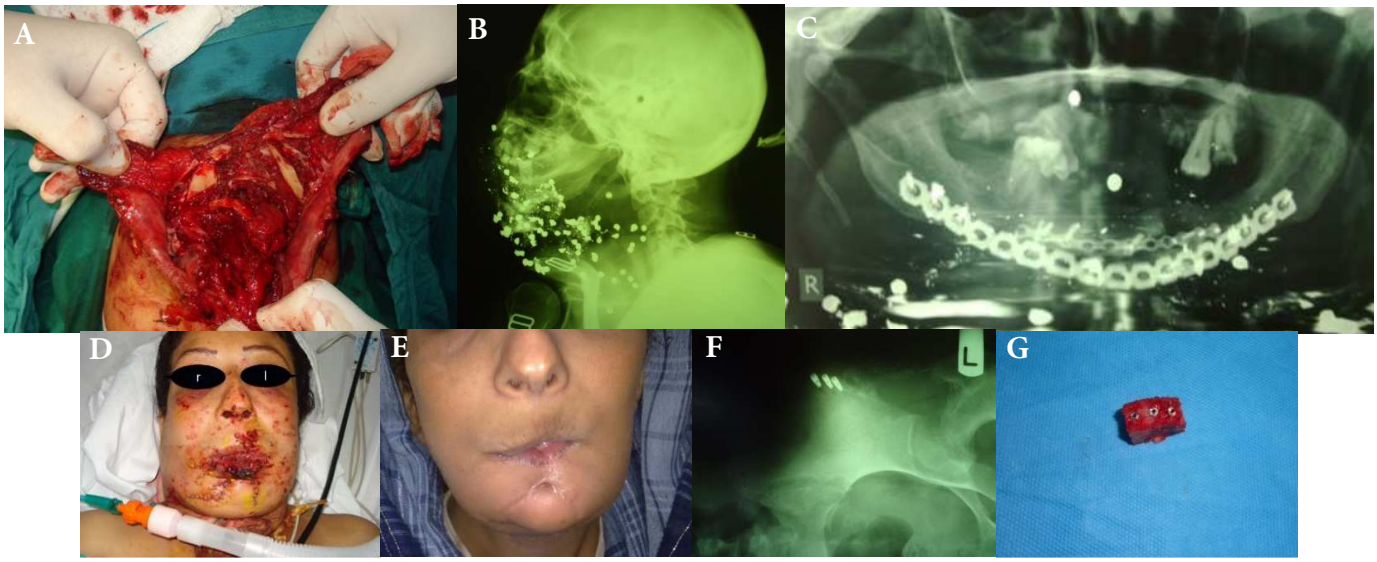

Figure 1. (A-C) A 37-year old woman with symphysis avulsion; **(D)** Debridement, fixation of bone segments, and wound closure were performed at the time of the accident; **(E)** two months after first step reconstruction; **(F,G) T**hree implants were placed in iliac bone 2 month later. Iliac bone graft with submerged implants was harvested and grafted to the symphysis area of the avulsive jaw

Figure 2. (A,B) A 28-year old man with maxillomandibular avulsion; (C, D, E) At the first stage debridement, a forehead flap, sterno-cleido-mastoid flap, free skin tissue graft from the tie and local mucosal flap were planed; (E, F) At the second step a tissue expander was used to close the forehead donor site before cutting the pedicle; (G) Note that the wound dehiscence formation at the mid-symphysis area

face were excluded from the study due to neurological deficit. Patients with projectile entry site away from face like neck, chest etc. and secondarily involving face were excluded from the study.

Data was analyzed using Statistical Package for Social Sciences (SPSS 20.0.1 for windows; SPSS Inc, Chicago, IL). Data was presented in the form of descriptive statistics. For all quantitative variables mean and standard deviation were presented. Frequency and percentages were presented for qualitative variables. These variables included gender, entry site of projectile, emergency airway establishment by entry site, types of emergency airway, wounds with underlying bone fractures managed with, open reduction and internal fixation in combination with soft tissue undermining, local flaps, distant flaps, free flaps, or wounds managed conservatively, time of intervention as early, delayed early or delay, single or multiple stage, injury to associated structures, wounds with bony reconstruction and complications following the management of those cases.

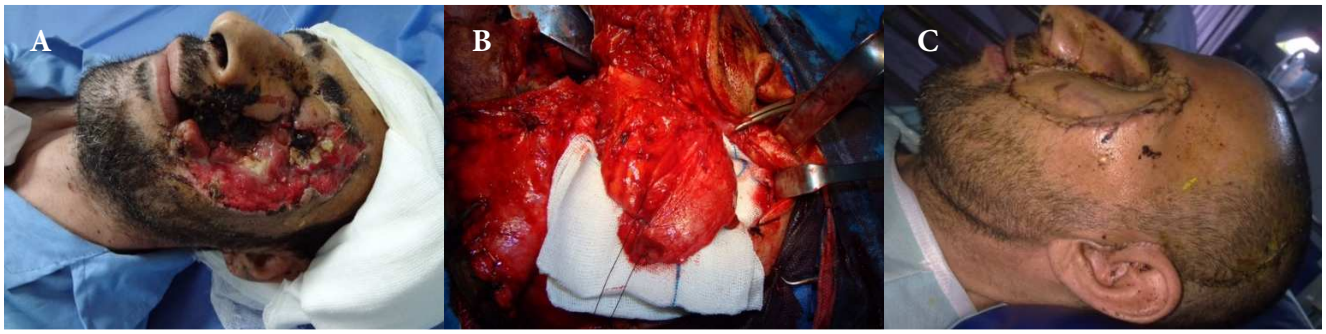

Figure 3. (A-C) A 34- year old man with mid-face avulsion. A temporalis flap with concomitant free skin graft was used to reconstruction

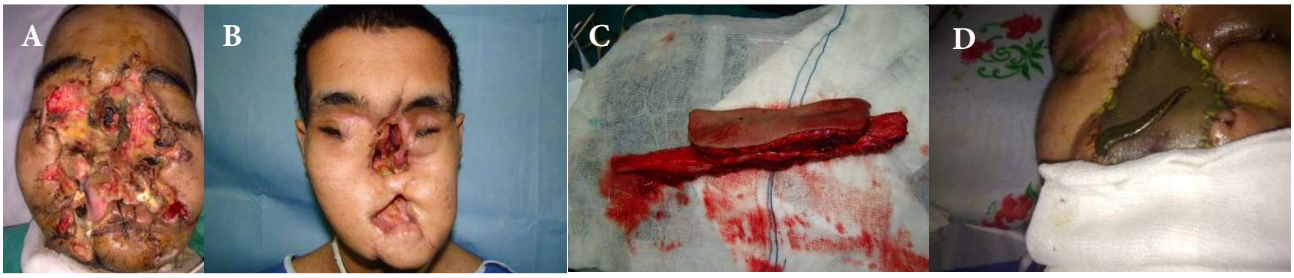

Figure 4. (A, B) A 24-year old man with bimaxillary and nose avulsion due to suicide; (C) A free vascular fibular flap was used for reconstructing the defect; (D) Due to a sign of necrosis leech therapy was performed. Note that the flap necrosis was seen after one week and the patient had been referred to receive a facial prosthesis

Results

There were a total of 14 patients with MGSWs during the 5 years of study period. There were 12 (85.7%) males and 2 (14.3%) female cases ranging in age from 18 to 42 years with a mean age of 27.34 years. The specific type of weapon used was identified as Kalashnikov in 2, sidearm in 4, and pellet gun in 8 cases. From the total of 38 cases, 11 (78.5%) involved the mandible and 3 (21.5%) involved the midface site (Table 1). Suicide was the main cause (50%) of gunshot. Ten (71.5%) patients required airway management. Tracheostomy was the most common method used (80%). Open reduction internal fixation (ORIF) was performed in all the patients. Half of the patients underwent delayed reconstruction and 71.4% of the reconstructions were done in more than a single stage (Table 2). 44.4% of the soft tissue flaps were either regional skin flaps or a combination of tissue expander and regional flaps. Most of the flaps (87.8%) were raised with a delayed early timing. The type of soft tissue management is given in Tables 3 and 4. 66.7% of the post-operative complications occurred early after surgery, while 40% were delayed. Facial nerve palsy accounted for one third of the complications followed by soft tissue contracture (26.7%) (Table 5). Donor site morbidity was seen in one case where free fibular flap was used and the toe was amputated after 2 months. Figures 1 to 4 show the results of our treatments for four selected patients.

Discussion

Epidemiology

More than 50% of attempted suicides, 14% of assaults, and 12% of accidental injuries occur in the maxillofacial region. MGSW has an incidence of about 6% and 22% of them comprises the mandibular GSW (5). Based on retrospective cohorts, the primary predictor variable in self-inflicted MGSW is the bullet trajectory. Johnson *et al.,* showed that coronal gun orientation might be associated with an increased fatality(6). MGSWs and their associated fatality has markedly decreased since the last 25 years. However, in the United States, they are still the second major cause of death due to injury.

Complications

MGSWs vary with the type of gun used. There are two main types of GSW: high-velocity and low-velocity. The outcome of high-velocity gunshot injury is usually fatal. The extent of the MGSW depends on a number of factors including size, shape, velocity, and point of entry of the given projectile. Moreover, the involved soft and hard tissues, the type of trauma, and the anatomy where the projectile is lodged are of paramount importance to the prognosis of the injury (7). MGSW might be associated with bullet embolus to the pulmonary artery (8). Moreover, ingestion of lead fragments after MGSW may result in rapid increase in blood lead level which must be fully evaluated. In this evaluation, all potential sources including

Table 1. Associated injuries according to entry site observed in 14 maxillofacial gunshot wound patients during a 5 year time span

Associated injuries	Mand. (%)	Mid. (%)	Total
Airway	9 (90%)	1 (10%)	**10**
Globe			**4**
Retinal detachment	2 (100%)	-	
Direct blindness	-	2 (100%)	
Truisms	11(100%)	-	**11**
Infection	2 (66.7%)	1 (33.3%)	**3**
Facial nerve	2 (40%)	3 (60%)	**5**
Cranium	3 (100%)	-	**3**
Parotid or submandibular glands	2 (100%)	-	**2**
Major Vessels	-	-	**0**
Total	**31 (81.6%)**	**7 (18.4%)**	**38**

Table 2. Distribution of different interventions according to the time and number of stages in 14 maxillofacial gunshot wound patients during a 5 year time span

Intervention	Immediate w/o bone graft			Delayed			Delayed w composite free flap			Total
Site	Mand.	Mid.	**Total**	Mand.	Mid.	**Total**	Mand.	Mid.	**Total**	
Single stage	-	-	**0**	-	-	**0**	3	1	**4**	4 (28.6%)
Two stage	2	1	**3**	4	2	**6**	-	-	**0**	9 (64.3%)
Multi stage	-	-	**0**	1	-	**1**	-	-	**0**	1 (7.1%)
Total	**2**	**1**		**5**	**2**		**3**	**1**		**14**
	3 (21.4%)			**7 (50%)**			**4 (25.6%)**			

Single stage = soft and hard tissue replacement simultaneously, Two stage = bone graft was performed at a separate stage

Table 3. Type of soft tissue interventions according to entry site

Type of soft tissue intervention(s)		Mand.	Mid.	Total
Conservative treatment with soft tissue undermining and primary closure		1	-	1
Secondary healing		-	-	0
Local flap or distant flap	Intra-oral	1	-	1
	Extra-oral	5	3	8
Free fibular flap		3	1	4
Total		**10**	**4**	**14**

recent environmental exposures, any remaining bullets in body, and long-term body stores such as bone should be considered (9).

The severity of gunshot injuries depends on the distance to the gun muzzle in most cases. Wound infection and vascular and neurological injuries might happen even from close distance. Vascular injuries can result in pellet embolism followed by tissue infarction by arteriovenous fistulae. In case of lead pellets, plumbism can be another possible complications (10).

Imaging

Oral radiologists have been increasingly dealing with GSWs especially the non-fatal low-velocity MGSWs. Prediction of missile trajectory will aid in the assessment and localization of the damage caused by MGSW.

Determining the precise anatomical location of projectiles using conventional radiological techniques is challenging due to their two-dimensional representation. Moreover, every projectile typically leaves it all clinical and radiological pattern of injury. Therefore, computed tomography (CT) has long been the standard diagnostic tool for assessing GSW tissue damage. Metal objects can cause artefacts in CT scans and make it difficult to identify adjacent anatomical structures. By contrast, cone-beam computed tomography (CBCT) provides artifact-free three- dimensional images (11). Therefore, CBCT is more suitable than CT in the diagnostic imaging of injuries caused by high-density projectiles (12).

Table 4. Distribution of regional and distant flaps according to time of intervention(s) and entry site

Type of regional or distant flap	Early		Delayed early		Delayed		Total
Site	Mand.	Mid.	Mand.	Mid.	Mand.	Mid.	
Sterno-cleido-mastoid flap (skin-muscle)	-	-	1	-	-	-	**1**
Forhead flap (skin-muscle)	-	-	-	1	-	-	**1**
Platisma flap (skin-muscle)	-	-	1	-	-	-	**1**
Temporal flap + skin graft	-	-	-	1	-	-	**1**
Regional skin flap	-	1	-	1	-	-	**2**
Tissue expander + regional flap	-	-	1	1	-	-	**2**
Intra oral flap (mucosal)	1	-	-	-	-	-	**1**
Total	**1**	**1**	**3**	**4**	**0**	**0**	**9**
	2		**7**		**0**		

Table 5. Post-operation complication(s)

Post-operation complication(s)	Early		Delayed early		Delayed		Total
Site	Mand.	Mid.	Mand.	Mid.	Mand.	Mid.	
Dehiscence	2	-	-	-	-	-	2
Infection	1	-	1	-	-	-	2
Flap necrosis	-	-	-	-	-	1	1
Contracture	-	-	-	-	3	1	4
Donor site morbidity	-	-	-	-	1	-	1
Facial nerve palsy	2	3					5
Sinusitis							
Trismus							
Others	-	-	-	-	-	-	-
Total	**7**	**3**	**1**	**0**	**4**	**2**	**15**
	10		**1**		**6**		

Moreover, ultrasonography can be used as a surgical guide to detect the pellet's positional relationship accurately relative to important soft and hard anatomical structures. Ultrasonographic surgery has been suggested as an accurate, safe, and cost effective alternative with minimum post-operative morbidity and surgical complications (13, 14).

Management

MGSWs are generally considered benign, since the mortality related to the facial trauma is uncommon. However if airway patency and hemorrhage are not controlled properly, it may be fetal. There have been reports of remaining bullets in the maxillary sinus for more than 50 years (15). These injuries almost always present as a compound and/or comminuted fracture with an external wound. Their management mostly requires establishment of emergency airway and ORIF. The key to satisfactory results in MGSW management is early operative intervention since it is associated with superior psychosocial profile and esthetics, reduced hospital stay, and early functional rehabilitation (16-18). Regardless of the degree of complexity, the treatment outcomes of significant facial trauma largely depend on "thorough physical and radiographic examinations, appropriate diagnoses, and treatment based on sound prosthodontic and surgical principles" (19). Immediately after injury, advanced protocols for trauma life support should be followed with patient stabilization as the primary goal. In MGSWs, it is often recommended to remove the projectile. Sometimes MGSWs may require multiple surgical interventions.

Reconstruction

In case of nonunion, the recommended surgical approach includes a second surgery which is performed using reconstruction plates possibly after hyperbaric oxygen (HBO) treatment. There have been debates on the effectiveness of "delayed definitive" treatment including serial debridements versus the most recent concept of "immediate reconstruction."

It should be noted that MGSWs will not necessarily result in extensive destruction (20). Some case reports have suggested that gunshot injuries can be treated primarily where undermining of the edges of wound and regular well-lubricated dressings comprise the key management elements (21). In case of extensive damage, definitive microvascular tissue transfer is the preferred surgical intervention, despite possible long-term functional and cosmetic complications. The current standard treatment is currently considered to be "vascularized fibula flap" for defects greater than 6 cm. The advent of vascularized flaps has increased the reliability of immediate reconstruction of large mandibular defects. According to the literature, the success rate of vascularized free flaps compared to free bone grafts have increased from 50% to 90%. The final reconstruction of the defects should include rehabilitation of the form and function with dental prostheses or dental implants. Vascularized fibula flaps may result in mandibular height discrepancies. Therefore, the major concern in vascularized tissue transfer has been insufficient height to achieve the occlusal plane. Onlay iliac graft, distraction osteogenesis (DO), and double-barrel variation of the vascularized flap technique has been proposed as possible treatment alternatives as well. Nonvascularized anterior iliac crest grafts offer numerous advantages, such as providing adequate volume and shape of bone, low donor morbidity. Moreover, the distant location from the mandible facilitates a multiteam approach. Whatever measure followed, obtaining adequate aesthetic and functional rehabilitation should be the main final goals of reconstruction (22, 23).

Lateral circumflex femoral artery perforator (LCFAP) flap has also been suggested for the immediate reconstruction of severe MGSWs. LCFAP flap ensures an intact vascular system which makes it a reliable source for the reconstruction of maxillofacial avulsive soft tissue losses (24).

Several improvements of the techniques mentioned previously remain possible. First, the introduction of a new osteotomy device such as piezosurgery could provide better bone healing by medullar and periosteal preservation. Second, the use of computer-assisted conception should provide custom-made devices perfectly adapted to achieve the best morphologic results. Third, automation of the distraction devices combined to their miniaturization should not only improve our result, but also reduce disadvantage on patients' social life by reducing their social stigmatization as well as the protocol duration. Moreover, the use of drug release into the bone callus could also improve our DO results and probably protocol duration. Major developments are required to be made in these techniques in to become a real alternative to fibula free flaps (FFF) and DO from both economical and technical points of view (25).

Oral rehabilitation

Implant-supported fixed prostheses, implant-retained removable overdentures, and implant-supported removable partial dentures (RPDs) have been used for the final rehabilitation of GSWs. Screw-retained fixed prostheses with acrylic resin teeth and metal substructures have been traditionally prescribed for implant-supported rehabilitation of the edentulous mandible. Their advantages include ease of retrievability, low cost in comparison to porcelain, as well as ease of repair.

Unlike normal mandible and maxilla anatomy, bone grafts often provide the opportunity for tripod implant placements (26). The tripod concept or "staggered implant placement" was developed to avoid the bending forces exerted to the implants placed along a straight line (27). In this technique, one implant is being placed in the middle and more than two implants are placed in posterior mandible to support the prospective prosthesis and redirect the occlusal forces axially and potentially increase the implant survival.

Post-operative Complications

Nonunions may be defined as more than 8 weeks' delayed healing. The causes of nonunion are multifactorial. Osteomyelitis, edentulous mandible, alcohol and drug abuse, delayed treatment, teeth in the fracture line, improper reduction, and poor fixation are among the causes. Nonunion is generally characterized by pain and abnormal mobility after treatment. Malocclusion may be present in dentate cases and mobility exists across the fracture line. Radiographs demonstrate no evidence of healing and, in later stages, show rounding off of the bone ends. Although the main reason is thought to be early mobilization, the new fixation systems lessen the frequency of this complication. Also, it has been suggested that even without maxillomandibular fixation, patients must be encouraged to regain motion, hygiene, and nutrition. It has also been stated that only gaps less than 3 mm are expected to heal without the aid of graft materials. Lack of proper wound closure may also result in contamination of the fracture site and infection-related osteomyelitis. A decreased blood supply can lead to delay in healing, as well. Sometimes nonunion cases may be converted to delayed union caused by immobilization. However, open reduction is recommended when conservative treatment fails. The recommended protocol for the operative treatment of nonunion in the mandible is as follows: an extra oral approach, debridement of the infected and necrotic tissues down to the healthy and bleeding bone, placement of a rigid reconstruction plate, and use of bone substitute materials when necessary (27).

HBO treatment is an adjunctive therapy for delayed or nonunion of fractures. Experimental studies have shown that HBO treatment increases both bone generation and the removal of necrotic bone tissue. However, there is still little comparative clinical evidence for the use of HBO treatment's effectiveness in nonunion of fractures.

Conclusion

Facial GSWs frequently involve mandible with more likely requirement of establishment of emergency airway and ORIF. Early management of GSWs with local flaps results in better psychosocial profile, aesthetics, reduced hospital stay and faster functional rehabilitation.

Conflict of Interest: 'None declared'.

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