MANAGEMENT OF GUNSHOT INJURIES IN THE MAXILLOFACIAL REGION: A REVIEW

1ª Dr. Abhishek Sharma, 2ª Dr. Vishal Bansal, 3ª Dr. Prajesh Dubey and 4ª Dr. Kunal Marwah

1ª Post Graduate Student, Department of Oral & Maxillofacial Surgery, Subharti Dental College & Hospital, Meerut (U.P.), India.
2ª Professor & Head, Department of Oral & Maxillofacial Surgery, Subharti Dental College & Hospital, Meerut (U.P.), India.
3ª Reader, Department of Oral & Maxillofacial Surgery, Subharti Dental College & Hospital, Meerut (U.P.), India.
4ª Post Graduate Student, Department of Oral & Maxillofacial Surgery, Subharti Dental College & Hospital, Meerut (U.P.), India.

*Corresponding Author: Dr. Abhishek Sharma
Post Graduate Student, Department of Oral & Maxillofacial Surgery, Subharti Dental College & Hospital, Meerut (U.P.), India.

ABSTRACT
As the use of firearms have become more prevalent in society, both the numbers of homicidal and suicidal victims has increased. Injuries from gunshot wounds of the face and neck, vary in extent and significance, forming a spectrum from trivial to life-endangering situations. The face and the neck have many vital structures confined to a small area of the body, and hence, it has a greater potential of leading to a fatality in the event of trauma. The severity of impact varies upon type of weapon and closeness of the shot. Management in terms of surgical exploration and removal of bullet or conservative management leaving bullet in situ, is still a matter of debate. The initial care of facial gunshot wounds strictly adheres to the basics of trauma resuscitation. Early and appropriate surgical management have proved to be influential on the final outcome and aesthetic result. Treatment of gunshot injuries should be planned and carried out carefully. It takes different stages and procedures to achieve the targeted treatment plan. Prevention and control of infection are important in the success of the treatment.

KEYWORDS: Firearms, Gunshot wounds, Trauma resuscitation.

INTRODUCTION
Firearms were introduced in Europe during the 14th century and presented surgeons with a new and challenging form of injury, the gunshot wound. Unlike most earlier forms of penetrating injuries, which were relatively clean and had obvious paths of penetration, these new wounds were considerably more contaminated and had penetration pathways that were unpredictable. Infection, rather than direct trauma by the bullet, was most frequently the prime cause of death.[1] Maxillofacial gunshot injuries have been described in peacetime (related to suicide, homicide, or accidental situations)[2] and during wars[3], but currently they are reported rarely. There is an increasing incidence of gunshot injuries worldwide, particularly those involving the face.[4] Out of all gunshot injuries, 14% result in maxillofacial injuries.[5] Although there has been an increase in the incidence of gunshot wounds to the face, maxillofacial injuries are still not as common as those to other regions of the body.

Gunshot injuries can be clinically categorized according to their presentation.[6,7]
(a) Penetrating wounds – These are wounds caused by missiles of low impact velocity in which a small point of entry is found with the missile embedded in the tissue (Fig. 1).
(b) Perforating wounds – Missiles of high velocity pass right through the tissues with entrance and exit wounds. In general, exit wounds are larger than the entrance wounds (Fig. 2).
(c) Avulsive wounds – Massive wounds with avulsion and loss of tissue can be produced by a variety of weapons. It is usually caused by high velocity missiles or rapidly moving artillery or mortar fragments (Fig. 3).

The ideal time and method of treatment remains a constant issue of debate.[8,9] Facial gunshot wound patients must be initially managed in accordance with the algorithmic advanced trauma life support (ATLS) protocol.[10]

The present article aims to review the incidence of gunshot injuries in the maxillofacial region, different types of bullets and their velocities, mechanism of injury, and management including fluid and electrolyte balance, antibiotic prophylaxis, soft tissue coverage and hard
Mechanism of Gunshot Injury

Practically, there is a balance between velocity, projectile mass, and projectile size that governs the amount of energy transferred to the target and resultant tissue wounding. These factors govern the four components of projectile wounding: penetration, permanent cavity formation, temporary cavity formation, and fragmentation.\textsuperscript{16} Bullet at first, crushes structures along its track, causing temporary cavitation, shearing and compression, sometimes tearing structures (as with solid abdominal viscera) or stretching inelastic tissue (the brain). As tissue recoil and hot gases dissipate, soft tissue collapses inwards, and hence, a permanent cavity is formed. Secondly, kinetic energy transfer occurs during retardation of the bullet and causes damage outside the tract.\textsuperscript{17}

Classification of Firearms & Bullets

Firearms are generally classified as handguns, rifles, and shotguns. Handguns are also referred to as pistols and revolvers, depending on their mechanical actions. Shotguns typically are smoothbore weapons that fire shells filled with lead shot of various sizes. Some shotguns may be modified with rifled barrels to fire shells containing a solid lead projectile referred to as a slug. Rifles and handguns are classified by caliber (Fig. 4). Firearm projectiles are referred to as bullets. Simple lead bullets referred to as wadcutters are inexpensive and often used as target rounds. Jacketed bullets with exposed lead tips (soft points) are designed to expand on impact for maximum tissue destruction (maximum permanent cavity) and are typically designed for hunting.\textsuperscript{16} The modern bullet is usually a lead projectile partially or wholly encased in a copper jacket (Fig. 5, 6). The amount of injury a bullet can cause is primarily dependent on its velocity. Bullet velocity is classified as low, under 1000 feet/sec; medium, between 1000-2000 feet/sec and high, above 3000 feet/sec. A bullet requires a certain mass because of factors such as accuracy, projector and maintainence of velocity.\textsuperscript{18}

Characteristic of Gunshot Wounds of Various Missiles

The impact velocity is the most important determinant of wounding capacity. The shape of a bullet is crucial in overcoming air-resistance in flight. Velocity of impact is also dependent on drag and retardation factors. In addition to the cavitation, there is a ‘splashing’ effect when a high velocity missile hits the surface of the body which is analogous to the upward splash produced when a pebble is dropped into water. The heat generated by a high-velocity missile is insufficient to sterilize it, but may cause damage to susceptible tissue, particularly blood vessels.\textsuperscript{19} This may be a factor in both primary and secondary haemorrhage, particularly as the elasticity of blood vessels tends to protect them from damage by direct impact. In general, a high-velocity bullet will produce a small entrance and a large exit wound. Shotguns were originally designed to be used on small fast-moving game and typically fired small pellets that dispersed in flight to form a pattern. Shotgun wounds can

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tissue reconstruction and complications related to maxillofacial gunshot injuries.

DISCUSSION

The majority of civilian firearm injuries are sustained from handguns (86%), followed by shotguns (8%) and rifles (5%). Approximately 12 to 14% of unintentional and assault gunshot injuries involve the head and neck, whereas 51% of self-inflicted gunshot injuries involve the head and neck.\textsuperscript{5} Firearms are implicated in 58% of male suicides and 37% of female suicides. Importantly, the number of patients surviving and requiring treatment of gunshot injuries outnumber firearm fatalities by approximately 5:1.\textsuperscript{11,12}

Ballistics is the science of projectile motion. Ballistic science seeks to explain the behavior of the projectile and is typically divided into 3 stages :

1. **Internal (or interior) ballistics** describes the forces that apply to a projectile from the time the propellant is ignited to the time the projectile leaves the barrel. An important consideration is barrel length. In general, longer barrels (rifles) allow the force of the propellant to act on the projectile longer and generate higher velocities than do shorter-barreled weapons. In addition, a longer barrel serves to stabilize the bullet over longer distances.

2. **External ballistics** refers to forces that act on the bullet in flight. The primary factors that govern external ballistics are the weight and shape of the bullet.

3. **Terminal ballistics** is the study of bullet behavior once it impacts the target and is primarily concerned with how much energy is transferred to the target material and the resultant damage.

Traditionally, kinetic energy has been used as the basis to explain wounds caused by a gunshot. Simple physics can be applied to the projectile using the following formula:

\[ KE = \frac{1}{2} m v^2 \]

Where \( KE \) is kinetic energy, \( m \) is the mass of the projectile, and \( v \) is the velocity of the projectile. Thus, by doubling the mass of the bullet, its kinetic energy is also doubled, but by doubling the velocity, the kinetic energy is quadrupled.\textsuperscript{13,14,15} The power of the bullet is proportional to the dissipation rate of kinetic energy as it passes through the tissue. Wounding power is typically related to the amount of kinetic energy transferred to the target:

\[ P = m (V_{\text{impact}} - V_{\text{exit}})^2 \]

Where \( P \) is power, \( m \) is mass of the projectile, and \( V \) is velocity. Based on these formulas, the velocity of a projectile has traditionally been considered far more important than its mass in wounding power. Indeed, often guns are classified as low velocity (< 350 m/s), medium velocity (350–600 m/s), and high velocity (> 600 m/s).\textsuperscript{16}
be classified according to range. At a range under 1.52 m, the entire charge enters; between 3.04 and 6.04 m, the charge is still compact but some pellets have wandered; above 6.09 m, the wound is caused by pellets alone\(^{18}\) (Fig. 7).

Most handguns and rifles have barrels with internal grooves referred to as rifling that impart a spin to the bullet. This keeps the projectile stable in flight over longer distances. Eventually, all projectiles become unstable in flight because the center of gravity lies well behind the center of resistance (the bullet tip) causing them to take on various motions during flight. Gunshot injuries involving the orofacial region and neck may be simply classified as\(^{15}\).

1. Tangential  
2. Transverse  
   a. High-level  
   b. Mid-level  
   c. Low-level  
   d. Neck

In the facial region, missile injuries are alone in being capable of inflicting severe bone and soft-tissue disruption without transmitting force to central nervous system. The patterns of injury in the maxillofacial region depends according to the site of principal damage.

a) **Upper face** – Wounds of the upper face are most serious of all as these are the injuries likely to involve the eye or the cranial cavity. Injuries of the naso-etmoidal region are frequently associated with loss of the eye as well as cerebrospinal fluid leakage from the cribriform plate area. Penetration of the cranial cavity may occur via the orbital roof, the cribiform plate or the posterior wall of the frontal sinus whenever a missile traverses the upper face. If this happens, there is a grave risk of meningitis or permanent damage to cranial nerves in the area, particularly the olfactory.

b) **Middle face** – Traverse injuries to the middle face are not usually accompanied by complete separation of the maxillae from the base of the skull. At a slightly lower level, localized fragmentation of the maxillary alveolus commonly occurs but, because of the relatively soft consistency of maxillary bone, the shock wave does not produce fracture of teeth remote from the point of impact, as it tends to do in the mandible. Penetrating injuries of the antrum require special management because of the difficulty in obtaining primary skin cover. Tangential injuries in the mid-face frequently involve the parotid gland and may lead to parotid fistulae and the facial nerve and ear may also be damaged. Direct injury to the temporomandibular joint area may also lead to ankyloses but the chief danger here is from penetration of the cranial cavity through the squamo-typanic fissure.

c) **Lower face** – Injuries range from gross destruction of the lower face to simple mandibular fracture and it is unusual for missile wounds in this area to occur without fracture of the mandible. The impact of a bullet against the dense mandibular bone produces injury ranging from a small localized alveolar fracture to the more usual comminuted compound type. Transverse injuries at the mandibular angle, in which the missile passes through the base of tongue, constitute a much greater mechanical threat to the airway. Tangential injuries to the lower jaw may be accompanied by gross comminution, or even loss of bone and soft tissue, with relatively little encumbrance to the patient.

**The neck** – Wounds of the neck are not common and, surprisingly, are often not as serious as might have been expected. The elasticity of major blood vessels and nerves is such that they are frequently pushed from the path of a bullet. Direct damage to major vessels may lead to immediate fatal haemorrhage. Bullets or shrapnel lodged close to major vessels, or adjacent to the oesophagus, may erode the walls of these structures. Secondary infection, with the formation of para- or retropharyngeal abscesses, can occur. In the base of the neck, injury to the brachial plexus or penetration of the cervical pleura is a serious hazard and any injury to the spinal cord is a threat to life.

**Blast injuries** have the unparalleled capability to cause several categories of injury extending from thermal to blunt or penetrating multiple system injuries that are life threatening. High energy explosive detonation results in extremely rapid (0.001 sec) conversion of a solid or liquid explosive into gases and sudden changes in atmospheric pressure. The gases expand rapidly, compressing the surrounding air, creating a supersonic “blast over-pressure wave”.

**Biologic Response To Gunshot Wounds**  
The transfer of kinetic energy from a projectile to tissue is a direct cause of tissue damage. In addition to the local physical damage that is produced, there are the effects of altered tissue physiology distant from the immediately damaged area that plays an important role in the overall morbidity of the injury. These effects include changes in microcirculation, regional circulation, electrolyte composition, water content, and metabolism. The contamination of the gunshot wound is exponentially enhanced by debris that is sucked into the wound secondary to cavitation.

**Treatment of Gunshot Injuries**  
The management of facial gunshot wounds can be divided into 3 phases\(^{20,21}\):-

1. Primary  
2. Intermediate  
3. Reconstructive

The primary phase includes the resuscitative efforts that are required to stabilize the patient. Especially important is the establishment of an airway and restoration of
hemodynamics. As part of the initial assessment, the oropharynx must be cleaned of blood, teeth, or bone fragments and examined. Loss of the airway is the single most likely cause of death in an isolated gunshot wound to the face. The airway should be controlled immediately via intubation when there is involvement of the base of the mouth and tongue or loss of skeletal support to the airway or in the presence of protracted intraoral bleeding. In addition to the potential development of hemodynamic instability and shock, excessive bleeding in an unintubated patient may severely compromise the ability to breathe. Initial attempts to control hemorrhage in the emergency department center on direct pressure and packing. Blind clamping should be avoided because of the attendant risk of damage to other structures. Standard methods for epistaxis control such as Foley catheters or specially designed balloon catheters will control most midface bleeding. In cases of mandible fractures, temporary reduction of the fracture may be required. If packing and selective ligation fail to bring severe hemorrhage under control, consideration must be given to either unilateral or, occasionally, bilateral external carotid artery ligation. Radiographs, including lateral and plain films, should be obtained prior to surgery to help determine the location and extent of injury as well as the potential location of the bullet or its fragments. The surgical treatment plan should always be approached in an orderly and systematic manner. Treatment objectives should include the following:  
- Repairing injuries to the eye and cranial nerves as well as protecting them from possible iatrogenic injury during surgery.  
- Preserving as much bony and soft tissue as possible.  
- Debriding only obviously nonviable tissue and removing accessible portions of bullets, wadding, or cartridge packing.  
- Stabilizing the bony framework by the simplest and most direct method feasible.  
- Closing the soft tissue primarily if possible.  
- Administering antibiotic therapy.  

In addition to lavage, all dirt and debris must be mechanically removed from the wound to prevent a tattoo scar as well as to minimize the chance of infection. The basic principles of surgical management of the gunshot wound are similar to those employed for other types of hard and soft tissue facial trauma: reduction and fixation of the fractures first, followed by closure of the soft tissue from the inside out. Closure must start intraorally for injuries that involve the mouth, thus converting a through-and-through defect to an extraoral wound. After this conversion is attained, the injury should be irrigated again, reprepared, and draped, and closed from the inside out. The intermediate phase includes supportive care and the prevention and treatment of complications, such as hemorrhage, infection, and sequestration. Proper wound care during this phase is mandatory. The patient’s fluid, electrolyte, and nutritional status should be closely evaluated. Early placement of nasogastric tube is helpful. The reconstructive phase of treatment involves patients who have some sort of residual defect. It is usually directed toward the repair of scars and soft tissue deformities, closure of fistulas, obliteration of bone defects, and restoration of dental occlusion. Most often, the kinds of deformity encountered at the reconstructive stage include the following:  
- Deficient soft tissue  
- Deficient bony tissue  
- Microstomia  
- Fibrous union of bone segments  
- Fibrotic ankyloses of the temporomandibular joint (with restriction of mandibular function)  
- Lack of satisfactory foundation for a prosthesis.  

General goals to be attained by reconstruction include the following:  
- Rebuilding facial features for functional as well as aesthetic reasons.  
- Restoring function of the eyes, nose, and mouth.  
- Closing the tracheostomy, if necessary.  
- Integrating the patient back into society.  

Reduction and fixation of bone segments using bone grafts, if needed. Since reconstruction involves both soft and hard tissue management, if a discontinuity defect exists, preparation should be made for bone grafting at the earliest time. After skeletal fixation, soft tissue coverage is crucial. In the acute and sub-acute setting, tissue coverage depends on:  
1) Wound dimension  
2) Overall patient status  
3) Surgeon’s prerogative  

Shortly after injury, it is generally preferred to attain more conservative wound coverage. Although some surgeons advocate free flaps, others prefer “temporary” coverage and defer lengthy definitive procedures to a time when the patient has stabilized.
CONCLUSION

The development of firearms heralded a new era in surgery as well as warfare. Evolution of more efficient weapons continues to force surgeons to improve techniques. Similarly, improvement in the management of gunshot wounds to the face has paralleled the advancement of oral and maxillofacial surgery. Firstly, it is essential that we follow the lines of basic management of facial and neck injuries, that is: securing the airway, controlling hemorrhage, identifying the other injuries and preventing an additional injury and repair of the
traumatic facial deformities, in that order. Secondly, local/regional radiological investigations (plain radiographs and CT scans) are vital tools in assessing collateral damage. Improvements in imaging and fixation techniques have resulted in an evolution in management, with an emphasis on earlier repair and a focus on improvement in quality of life. Prevention and control of infection are important in the outcome of the treatment success.

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