Ballistic Injuries of the Face and Mouth in War and Civil Conflict

A.J. GIBBONS AND D.W. PATTON

Abstract: **Ballistics is the science of thrown or projected objects. The consequences of ballistic injuries to the face may be devastating and lead to considerable disability and disfigurement. Reconstructive techniques for maxillofacial injuries have improved greatly since World War II; however, the basic principles for the initial, early and reconstructive phases of treatment have stood the test of time. This paper gives an overview of the management of ballistic injuries to the face and jaws.**

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Clinical Relevance: **Dental practitioners may need to provide dental treatment for patients who have sustained ballistic injuries to the face. An understanding of the principles of management, and the role of the dentist, is necessary.**

The management of injuries of the face changed dramatically during the twentieth century as a result of advances in medicine and technology. There is no doubt that war has been a major catalyst in the development of maxillofacial surgery. When the British Expeditionary Force went to France in 1914, it wasn't accompanied by a dental surgeon – that is, until General Douglas Haig developed a severe toothache in October 1914. He had to summon a French dentist called Charles Valadier from Paris to remove the molar tooth which was causing him considerable pain. Valadier was appointed as an Honorary Major in the RAMC and set up, in Wimereux, what was arguably the first maxillofacial unit. He was soon joined by an Armenian dentist from Harvard called Kazanjian. The unit immediately became overwhelmed by the huge number of maxillofacial injuries. Captain Harold Gillies (later Sir Harold Gillies), a New Zealand immigrant serving as a general surgeon at that time, came to visit Wimereux to learn the techniques being developed. From that point he decided to devote himself to the reconstructive management of the face and jaws. He was allowed to set up a maxillofacial unit in Aldershot in 1916 under the command of Colonel Sir Arbuthnot Lane. The unit received 2000 major maxillofacial injuries from the Somme in only 10 days. It was hopelessly over-committed and was transferred to Queen Mary's in Sidcup where more than 11 000 maxillofacial injuries were subsequently treated. It was over this period that the concept of inter-dental occlusion as the key to proper reduction of fractures, and the use of dental splints, was developed. Renewed emphasis was placed on posture to protect the airway and thorough debridement of wounds.

During World War II, reconstructive techniques were improved with the use of bone grafts and tubed pedicles. Antibiotics became available and stainless-steel wires were used for the first time to fix bone fragments directly. Extra-oral fixation devices were also introduced.[1]

Since World War II, further developments in surgical techniques, equipment, antibiotics, imaging and anaesthetics have taken place. Improved techniques for the internal fixation of maxillofacial fractures with bone plates have evolved, and the use of free tissue transfer using microvascular techniques has greatly improved the possibilities for soft-tissue reconstruction. Over the same period, developments in weapon ballistics have resulted in high-energy transfer wounds leading to greater tissue damage and loss (Figure 1).

WEAPON BALLISTICS AND TYPE OF INJURY

The energy which a missile transfers to the tissues of the face when it strikes is calculated by the formula:

$$KE = 1/2\ mv^2$$

where KE is the kinetic energy, m the mass, and v the velocity of the missile.

From this it may be seen that the amount of energy available can be quadrupled by doubling the velocity,

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Figure 1. *Effects of a high-velocity round to the face.*

but that doubling the mass only increases the energy available by the same factor. Ballistic research has therefore concentrated on producing rounds of higher velocity, but reducing the mass to allow soldiers to carry a greater number of rounds. In modern warfare, a much higher proportion of wounds are caused by fragmentation devices, such as bombs or shells, rather than guns. Other weapons, such as anti-personnel mines, are designed to maim rather than kill, placing a higher logistic and psychological burden on the enemy.

In military conflicts during the twentieth century, about 16% of injuries have been to the head and neck area,[2] even though this region anatomically accounts for only 12% of body surface area. Both penetrating ('military') and blunt ('civilian') trauma injuries occur in war. The middle and lower thirds of the face are the most commonly injured sites, probably as a result of the need to expose the face when observing targets. Blunt trauma tends to cause predictable linear fracture patterns in the mandible and maxilla, often with damage to the associated teeth, but generally without soft-tissue loss.

High-velocity missiles passing through the trunk or a limb tumble or yaw, increasing energy transfer and causing cavitation, devitalizing muscle, and sucking debris and bacteria into the wound. However, in the face there is no large muscle mass to absorb energy and cavitation is not the same problem. If the round strikes the jaws or teeth, the high energy transfer causes extensive comminution of the bone, with an explosive exit wound.

Because of the number of casualties caused by fragmentation devices, ballistic injuries to the face are commonly associated with penetrating injuries in other parts of the body, frequently involving a number of body cavities: the average number of wounds in casualties in the 1991 Gulf war was nine. Furthermore, other injuries may be present from associated blast or burns. Primary blast injuries are due to the blast wind ('fresh air travelling fast'). Secondary blast injuries are due to flying debris, and tertiary blast injury is due to the individual being thrown against the ground or other objects. The situation may be further complicated if chemical or biological weapons have been used.

INITIAL MANAGEMENT OF MAXILLOFACIAL INJURIES

The initial management of maxillofacial injuries follows Advanced Trauma Life Support (ATLS) principles. The main aim is to preserve life, to stabilize haemodynamically, and to evacuate promptly. The most important aspect of the initial management is the primary survey to assess and treat the ABCD (**A**irway with cervical spine, **B**reathing, **C**irculation, neurological **D**isability). The definitive care of maxillofacial injuries is best delayed until the casualty is in a major base hospital where more comprehensive resources and expertise are available: the role of a forward hospital is more likely to have been that of aggressive surgical resuscitation, stabilizing the casualty for rapid evacuation. Casualties may therefore arrive in the UK with facial fractures and dental injuries largely untreated.

Airway

Death within the first few minutes or hours of ballistic injury is commonly due to airway obstruction.[3] The most important aspect of the primary survey is to establish and maintain the airway, which is achieved in most cases with simple methods such as clearing debris from the mouth, a jaw thrust, and pulling the tongue forward. The airway is then maintained by posture or by a nasopharyngeal or oropharyngeal

Figure 2. *Severe soft-tissue swelling may necessitate a tracheostomy to protect the airway.*

airway. Such patients are more comfortable lying in a prone position, or sitting up with their head forward. If all else fails, a surgical airway may be required. In the emergency situation this should be a cricothyroidotomy, although this procedure is best avoided in a child below the age of 12 years. A larger proportion of patients will require a formal tracheostomy over the following hours as swelling increases (Figure 2).

In 'civilian' or blunt trauma, the maxilla may be displaced backwards and downwards along the inclined plane at the skull base, blocking the pharyngeal airway. A finger should be inserted behind the soft palate and the maxilla pulled forwards as an emergency procedure. The tongue may lose anterior support in bilateral mandibular symphyseal fractures, and if the patient is lying supine the tongue will drop back and occlude the airway. The airway may be established by pulling the tongue forward and maintained by a deep traction suture placed in the tongue to bring it forward with a definitive tracheostomy carried out later. Patients with maxillofacial injuries and airway problems are a high priority for evacuation to hospital, whereas patients with a stable secure airway have a lower priority.

Under the ATLS protocol, in blunt trauma resulting from a deceleration injury the cervical spine must be assumed to have been injured and

Figure 3. *Facial wounds may bleed profusely.*

should be immobilized until cleared by radiographs of the cervical spine. The chance of a neck injury has been estimated as 10% of casualties who are unconscious with a significant facial injury from blunt trauma. In a pure penetrating wound of the head and neck with no history of a substantial fall, the chances of a cervical spine injury is very small.

Breathing

Once the airway has been established and maintained, breathing is assessed by chest examination. In most penetrating injuries of the face, breathing is unaffected, but beware the stab wound of the neck that has penetrated the apex of the lung behind the clavicle.

Circulation

Following A and B, C is assessed. The blood supply of the face and jaws is good, and so bleeding can be extensive (Figure 3). Nonetheless, the degree of bleeding is easily overestimated. If the patient is clinically shocked, pale and clammy, with a raised pulse and lowered blood pressure, the possibility of bleeding into the chest, abdominal or pelvic cavities should be considered. Once the blood pressure begins to drop, the casualty has lost at least a third of his/her blood volume. Bleeding within the oral cavity and pharynx can also cause airway problems. Anterior and posterior ethmoidal vessels may bleed profusely. To arrest this, reduction of Le Fort fractures and the placement of anterior and posterior nasal packs should be performed. Epistats or Foley catheters may also be used to occlude the nasal airway.

If bleeding continues after the application of pressure to wounds, then the patient should be taken to theatre immediately to explore wounds and to tie vessels. Embolization of bleeding vessels may also be considered where facilities are available. If bleeding is torrential it may be necessary to tie off the external carotid artery.

Where bleeding cannot easily be controlled, a more recent concept, particularly in the military field, is that of controlled hypotension. Until the source of bleeding is controlled, the systolic blood pressure is maintained at 80 mmHg only, sufficient to perfuse the major organs, and just enough to give a palpable radial pulse, but helping to reduce the blood loss. Aggressive fluid replacement in the presence of uncontrolled bleeding has been likened to running the bath taps with the plug out.

Disability

A brief neurological assessment is made for any 'disability'. A high index of suspicion of head injury is warranted in all cases of severe maxillofacial trauma. A patient with maxillofacial injuries and a decreased level of consciousness may not be able to maintain a posture to help keep his/her airway patent and often needs airway support.

SECONDARY SURVEY AND DIAGNOSIS OF MAXILLOFACIAL INJURIES

In the immediate post-injury phase, the emphasis is to detect and treat life-threatening conditions such as an obstructed airway: the exact diagnosis of the maxillofacial injury is not a priority. In the secondary survey, a comprehensive examination is carried out in an attempt to identify more accurately the nature of the injuries. In ballistic injuries of the head and neck, a systematic examination is particularly necessary, as it is easy to be distracted by the striking appearance and bleeding of a major facial injury.

It is important to document injuries accurately and to re-evaluate ABCD at regular intervals. To diagnose maxillofacial injuries accurately it is essential to clean the patient up as an initial procedure. An accurate history of the incident is obtained, and signs and symptoms elicited. These include pain, swelling, bruising, deformity, loss of function, abnormal mobility, neurovascular disturbance and deranged occlusion. An assessment should be made of injury to, as well as loss of, soft and hard tissue. Ophthalmic injuries are frequently associated with zygomatic and midface fractures and a thorough ophthalmic assessment in these cases is mandatory.

Imaging of facial injuries comprises two views taken at right angles. When available, CT scanning often provides

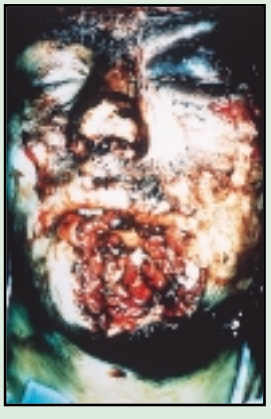

Figure 4. *Shattered teeth may be inhaled.*

Figure 5. *Inhaled tooth fragment.*

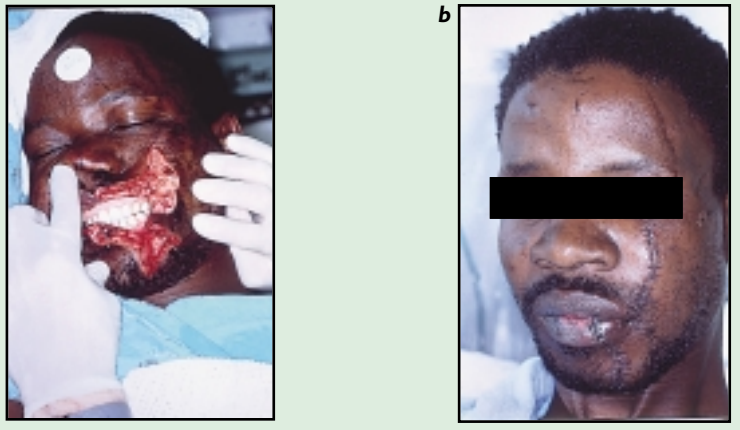

Figure 6. (a) *Meat cleaver wound to face, with no tissue loss.* ***(b)*** *Wound sutured.*

additional information.

The assessment of the teeth is important. If teeth, or fragments of teeth, are missing, they must as far as possible be accounted for: they may have been inhaled or ingested (Figure 4). Ingestion generally does not cause a problem, and the tooth will pass uneventfully through the alimentary canal. Inhalation is more serious, and a tooth will need to be removed early with bronchoscopy, or serious lung complications might ensue. A chest radiograph should be considered to check for teeth, bone or debris in the bronchi (Figure 5): if one has not been taken, and the casualty with missing teeth develops increasing breathing difficulty or coughs up blood, the presence of a tooth in the lung should be suspected. A complete tooth usually ends up in the right main bronchus, but a tooth fragment, such as an incisal edge, may work its way further down into the smaller airways and prove difficult to recover. If the fragment cannot be recovered with bronchoscopy, it may be necessary to perform a thoracotomy to remove the affected segment of the lung.

Having completed the primary and secondary surveys, resuscitating and stabilizing the patient, analgesia and tetanus prophylaxis should be given.

Even serious facial injuries may be less painful than might be expected, but fractured teeth exposing the pulp can be very distressing for the casualty. Simple dressing of the pulp can be far more effective than opiate analgesia.

As maxillofacial injuries are generally open into the mouth and contaminated, penicillin should be administered. If the wound communicates extensively with the mouth, metronidazole may be added and, if skin is involved, flucloxacillin.

EARLY SURGICAL MANAGEMENT

The aims of early surgery are to preserve tissue, minimize infection and provide the optimal environment for definitive reconstruction.

The soft tissues of the face have an excellent blood supply and tissue loss is frequently more apparent than real (Figure 6). Initial treatment comprises copious irrigation of wounds and the removal of non-vital tissue and foreign bodies. It is important to maintain tissue wherever possible, and not to perform wide excision.

Wound Closure

After reduction of fractures, if the wound is less than 24 hours old, then primary closure can be considered. This should be performed in layers with no tension and with good haemostasis. Drains are not always required but may be placed if there is any doubt about the adequacy of wound debridement. If bone is exposed it must be covered.

If the wound is more than 24 hours old or heavily contaminated, then delayed primary closure should be considered with initial packing or dressing of wounds. A further inspection of the wound is made 24–48 hours later and the wound closed with drains if clear of infection.

In closing facial wounds one should work from inside to out, closing oral mucosa before deeper muscle layers and then skin. Any damage to the branches of the facial nerve should be noted and, if nerve ends are identified, an immediate microneural repair is carried out if the facilities are available. If not, nerves are tagged with a non-resorbable suture before wound closure to assist with later repair. The presence of scar tissue makes late repair of nerves more difficult.

Bone Injuries

The early management of bone injuries comprises the reduction of fractures and intra-oral fixation of the teeth in occlusion. Unless severely damaged or loose, teeth are saved even if they lie in the line of fracture. Where possible, mini plates are inserted to stabilize fractures, which allows the

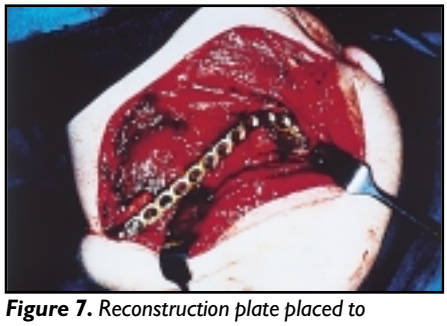

Figure 7. *Reconstruction plate placed to maintain bone ends in correct position before bony reconstruction.*

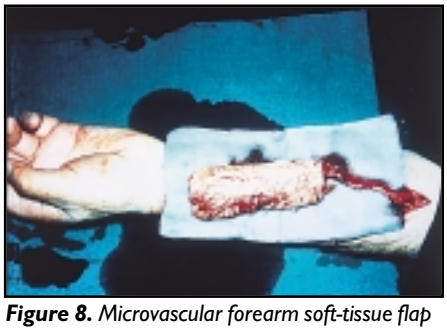

Figure 8. *Microvascular forearm soft-tissue flap based on radial artery.*

Figure 9. (a) *Immediate postoperative view of free flap reconstruction of extensive high-velocity gunshot wound to left lower face. A radial artery forearm flap was used to reconstruct the lip. In addition, a deep circumflex iliac artery composite flap with iliac bone, fat and skin was used to reconstruct the body of the mandible and overlying soft tissue.* ***(b)*** *Final result, showing an acceptable aesthetic result after further surgery. A tongue flap was used to reconstruct the vermilion border, the deep circumflex artery flap was debulked and the left oral commissure was revised.*

intermaxillary fixation to be removed and the airway to remain fully patent.

In cases where mandibular bone has been lost, reconstruction plates (Figure 7) or external fixators may be used to maintain the bone ends in their correct anatomical positions and definitive reconstruction is undertaken once soft-tissue healing has occurred. In contrast, the early repair of the midface can be performed at 7–10 days[4] with a rib graft forming a vertical nasal bar. At the base of the nasal bar between the zygomas, a further rib graft is placed horizontally. These grafts support the midface in height, width and projection. They help prevent soft-tissue contracture and form a scaffold for later definitive nasal reconstruction, subsequent bone grafts and scar revision.

Adequate nutrition and good oral hygiene are essential. If swallowing is difficult or intra-oral wounds have not been fully closed, then nasogastric feeding is indicated. In addition, psychological assessment and support should be instigated.

DEFINITIVE RECONSTRUCTION

Many long-term reconstructive problems are caused by soft-tissue scarring. It is therefore important in the early management of maxillofacial injuries to reconstruct wounds early where possible.[5] The aims of definitive reconstruction are to restore function and aesthetics. Preserving dental arch relationships helps create lip seal and improves speech, mastication, swallowing and respiration. Bone loss may be restored with iliac crest, rib or calvarial non-vascularized bone grafts.

A mush and mesh technique, using cancellous bone, has been used to reconstruct mandibles with large defects. In this technique, cancellous bone from the iliac crest is taken and placed into a formed titanium mesh mandible template. This is then placed between the two remaining bone ends to reconstitute the mandible and act as a platform for further osteogenesis. The soft-tissue bed into which the graft is placed must have a good blood supply and be free from infection. The mesh may be removed at a later date when mandibular bony healing has occurred. However, the use of vascularized free flaps such as the fibula flap has become commonplace in maxillofacial reconstruction, and has resulted in better functional and aesthetic outcomes.

Recently, callus distraction techniques have been used to reconstruct bony defects.[6] Using Illizarov's principles, an osteotomy is

KEY-POINT BOXES

- Antibiotics
- Prolonged general anaesthesia
- Imaging
- Open reduction techniques
- Rigid fracture fixation
- Free tissue transfer
- Osseointegrated implants

Box 1. *Important advancements in maxillofacial surgery.*

- Velocity more important than mass
- If hits thin bone shatters it
- If hits thick bone or teeth causes tissue destruction and loss

Box 2. *Energy transfer of bullet.*

- Airway vital – may require surgical airway
- Bleeding – if severe may tie external carotid artery
- Hypotension – beware covert bleeding in chest or abdomen
- Possibility of cervical spine injury in blunt trauma
- Beware inhaled foreign bodies

Box 3. *Initial management.*

- Soft-tissue injury
- Hard-tissue injury
- Soft-tissue loss
- Hard-tissue loss

Box 4. *Maxillofacial assessment in the secondary survey.*

- Thorough debridement – preserve tissue
- Close if possible
- Consider packing and review 24 hours later if heavily contaminated
- Tag severed facial nerve branches

Box 5. *Early soft-tissue management.*

- Reduce fractures
- Preserve teeth
- Keep bone ends in position with intermaxillary fixation, reconstruction plates or external fixators

Box 6. *Early hard-tissue management.*

- Early soft-tissue reconstruction prevents scarring and contracture
- Restore soft tissues with flaps
- Good blood supply to area and absence of infection important for bone grafts
- Restore bone with non-vascularized grafts, vascularized grafts or distraction osteogenesis

Box 7. *Definitive reconstruction.*

performed in the mandible at some distance from the bony defect. External fixators are applied to the three fragments of bone. The osteotomized bone is then moved towards the defect, causing new bone formation in its wake. When the osteotomized bone end meets the other side of the bony defect, a further operation is performed to remove any residual interposing soft tissues and to freshen the bone ends. Healing then occurs across this small defect.

Skin grafts and random and axial skin flaps may be used to close skin defects. For more extensive wounds, muscle flaps may be utilized. Vascularized free flaps, such as the radial forearm flap (Figure 8), are particularly useful in replacing lost tissue.

Complex defects may be reconstructed using more than one flap (Figure 9). Composite flaps of bone and soft tissue, such as the deep circumflex iliac artery flap from the pelvis, give large amounts of tissue and are particularly useful in reconstructing severe mandibular defects.

Osseointegrated implants may be placed into reconstructed bone once it has an established blood supply, to restore the dentition. Facial osseointegrated implants in the piriform fossa region, the orbital rims or the zygomatic arches may be used to anchor a facial prosthesis. Conventional obturator and denture techniques can also be used to reconstruct maxillary defects.

SUMMARY

Ballistic injuries of the head and neck are initially managed according to established ATLS principles, with particular emphasis on airway preservation. Care is required not to overlook life-threatening injuries, particularly in the abdomen and chest, which are more likely to be the source of hypovolaemic shock. Avulsed teeth or fragments of broken teeth must be accounted for as far as possible.

Adequate debridement and drainage with the early closure of soft tissue and the stabilization of bone ends in their correct anatomical position is the mainstay of primary treatment. Reconstruction of facial tissue loss requires the area to be free of infection and have a good blood supply. Early reconstruction prevents soft-tissue scarring and contraction.

With prompt resuscitation and initial surgery preparing the environment for definitive reconstruction according to the surgical principles elucidated above, and summarized in the key-point boxes, acceptable functional and aesthetic results should be obtained in the management of maxillofacial missile injuries.

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ABSTRACT

CAN WE ALWAYS BELIEVE OUR PATIENTS?

Validation of Self-Reported Medical History Data in Dental Charts. B.L. Stewart, W.A. Sabbah and A.M. Alrasheed. *Saudi Dental Journal* 2003; **15:** 33–37.

This simple piece of research may have uncovered a hornet's nest. The authors assessed the accuracy of medical and demographic data entered by patients on their dental charts by comparing these to data abstracted from medical records. A total of 246 sets of dental and medical records were randomly selected at an Armed Forces Hospital. The study was well structured with assessment of examiner reliability.

It was found that, although there was moderate agreement between the two sets of charts on demographic issues, there was low agreement in the reporting of medical conditions between the two sets of records. Particular issues found to be at odds were the low reporting to the dentist of hepatitis B, blood transfusions, high blood pressure and renal disease. Concerns were also raised regarding the reporting of a range of medical problems, including epilepsy, sickle-cell anaemia, leukaemia and abortion.

In discussing why this was found, the authors suggest that patients may be ignorant of the medical condition, consider the questions an invasion of their privacy, or may be aware that, if the conditions were divulged, dental treatment could be postponed or cancelled.

The authors suggest that dentists should not rely totally on self-reported medical histories, and ideally should have access to patients' medical records or database. They also proposed a universal system of recording diagnoses of medical conditions to enable different healthcare workers to read and understand medical files.

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