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Clinical Strategies in the Management of Complex Maxillofacial Injuries Sustained by British Military Personnel.

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Abstract

The maxillofacial injuries sustained by British troops requiring aeromedical evacuation to the United Kingdom are almost exclusively treated at The Royal Centre for Defence Medicine in Birmingham. As a result the Maxillofacial Department has collectively gained extensive experience in the management of ballistic injuries. In many cases the most successful outcomes have been achieved by using traditional strategies combined with contemporary techniques. This paper will highlight the types of injuries sustained and discuss some cases that typify those the department has managed.

Introduction

The Royal Centre for Defence Medicine (RCDM) is based at University Hospitals Birmingham NHS Foundation Trust (UHBFT). It treats the majority of British military personnel medically evacuated from around the world. The unit at UHB has previously described the epidemiology of maxillofacial injuries evacuated to the UK between June 2001 and December 2007 [1]. Maxillofacial injuries represented 7% of injuries evacuated to the UK in 2005, 9% in 2006 and 18% in 2007, with an overall incidence between 2005 and 2007 of 13%. The incidence of maxillofacial injuries in the 20th century has previously been quoted as 16% of total battle injuries [2], although more recent analysis of the conflicts in Iraq and Afghanistan have seen maxillofacial type injuries occurring in up to 29% of United States military personnel [3].

The immediate management of injuries sustained in operational theatre is undertaken as part of the overall efforts to preserve life and limb. Maxillofacial injuries are often non-life threatening and their management can be delayed, other than manoeuvres required to preserve life. Maxillofacial injuries carry a significant risk of airway compromise, which may be compounded by concomitant head injury. Endotracheal intubation is therefore often required prior to evacuation. It may be necessary to undertake oro-and naso-pharyngeal packing to obtain haemostatic control in complex injuries. Many maxillofacial injuries, particularly those sustained following Improvised Explosive Device (IED) detonation, will only require basic debridement of soft tissue injuries prior to aeromedical evacuation to RCDM. In the current operational tempo of Afghanistan there have been increasing number of soldiers evacuated who have been injured by high energy transfer rounds. These injuries are characterised by extensive soft and hard tissue damage, often with tissue loss. The extent of non-viable tissue may be greater than is first apparent as a result of haematoma, infection and the energy distribution associated with high energy projectiles. The full extent of tissue injury may not be appreciated until the casualty has been evacuated to the RCDM. Surgical teams stationed at the Role 3 facilities at Camp Bastion and Kandahar aim to preserve as much tissue as possible during primary management of these injuries.

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The Trauma Co-ordinator at RCDM will be alerted prior to the arrival of casualties from Afghanistan and this facilitates initial surgery within hours of arrival at the hospital if the clinical condition permits. On arrival at RCDM the Maxillofacial Trauma Consultant and Specialist Registrar will make an assessment of the relevant injuries and formulate a management plan accordingly. Once all life-threatening injuries have been addressed the focus is on tissue preservation and restoration of form and function. The complexity of these injuries means that multiple procedures may be required and the final reconstruction and rehabilitation will take many months.

The aim of this paper is to describe, through case-based discussions, the current management sequence for complex maxillofacial ballistic injuries and the eventual outcomes that can be achieved. All cases were of British servicemen evacuated from Afghanistan to our department between 01 January 2007 and 31 December 2009.

Case 1

This serviceman sustained an isolated high energy transfer gunshot wound, which entered the right upper neck and exited just beyond the chin point on the left hand side (Figure 1). Prior to aeromedical evacuation the airway was secured with an oral endotracheal tube and the orophayynx and entry/exit wounds packed. CT scans (Figure 2) clearly demonstrate the extent of the injury to the mandible and also the fragmentary nature of the damage. Associated with this was widespread, complex soft tissue damage with skin loss creating a compound injury.

Figure 1: *Initial appearance of high energy transfer injury on arrival at RCDM*

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In such a case the initial surgical episode would consist of the provision of a surgical tracheostomy and full examination and debridement of the wounds. Accurate documentation of the injuries is made including notation of the teeth present and those that may require extraction due to fracture or loosening. Once again tissue preservation is crucial and it is often possible to salvage teeth associated with dentoalveolar fragments as this may facilitate the final restoration and enhance eventual outcome

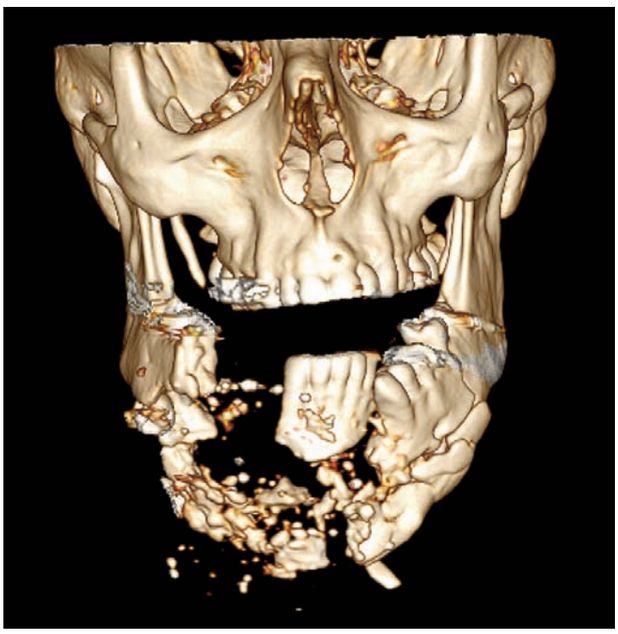

Figure 2: *3D CT demonstrating highly comminuted mandibular fracture*

Wound toilet is an essential aspect of management as infective complications are frequently seen and often involve organisms less commonly encountered in the United Kingdom such as Acinetobacter. Patients returning from Afghanistan have been documented by both American [4] and Canadian authors [5] as being colonized by unusual microbiological flora including *A. baumannii.* This bacterium is resistant to numerous classes of antimicrobials and suspected cases require strategies to limit further spread upon evacuation [5]. Although wounds will have been decontaminated prior to leaving Afghanistan this process is repeated prior to more definitive repair and appropriate antimicrobial therapy instigated.

Current trends in ballistic trauma management have suggested that early, definitive repair with composite free tissue transfer is beneficial even in hostile wound environments [6-8]. On initial inspection of the wound and the CT scan it is reasonable to conclude that injuries such as these will be associated with a significant defect that may require the use of free tissue transfer to achieve bony continuity. With this in mind it is essential that this option is not compromised by unnecessary or inadvertent ligation of blood vessels, such as the facial artery, that are a reliable choice for micro vascular anastomosis. It may be come apparent that these vessels are damaged and require ligation, but if they can be identified and preserved for future use then this should be done. However the wounds generated in military conflict differ from their civilian counterparts. The injuries sustained as a result of IED blasts and high energy rounds are a result of significantly greater forces with widespread destruction and tissue contamination [9]. Experimental studies have shown that high energy transfer injuries result in damage to soft tissue microcirculation, which can result in anastomotic failure if free flap reconstruction is undertaken too soon after such injuries [10]. This is compounded by the fact that associated limb injuries are common and catastrophic, often resulting in amputation. This has a major impact on the availability of donor sites and so limits reconstructive options.

Figure 3: *Immediate postoperative appearance demonstrating external fixator and primary closure of soft tissue wounds*

Contemporary mandibular fracture management techniques are largely driven by miniplate osteosynthesis. However in the face of such significant comminution, periosteal damage, and the through and through nature of the injury, there are obvious concerns regarding healing and potential infective sequalae of such an approach. Traditional strategies such as external fixator devices and intermaxillary fixation have a proven record of success in highly comminuted fractures, although may be associated with slightly higher complication rates than open reduction and internal fixation techniques [11]. Despite this; these strategies are routinely employed by the maxillofacial team at RCDM and to date have been associated with few complications. Modern incarnations of external fixators, such as that produced by Synthes©, are anatomically contoured, operator friendly and are associated with improved patient comfort and tolerance. It may be necessary to combine techniques and the injuries seen in Case 1 were managed by miniplate osteosynthesis of substantial dentoalveolar fragments to produce fewer, larger bony units which were then stabilised by a well contoured external fixator device. The next essential step is to achieve periosteal coverage of all bone to create an environment conducive to fracture healing. A tension free, water- tight mucosal seal must then be achieved either by primary closure or advancement of local tissue. The final stage in the initial surgical episode is skin closure. This will often require debridement of the wound edges and removal of skin that is clearly necrotic or that which is unlikely to survive. Following this it is usually possible to achieve primary wound closure, but if skin loss is more extensive consideration is given to alternative techniques such as local rotation-advancement flaps. Skin grafts are best avoided initially as the risk of infection remains and risks the healing of the graft. The immediate postoperative results can be seen in Figure 3.

Case 2

There has been a resurgence in the use of external fixators in the last few years to treat the complex bony facial injuries sustained by coalition servicemen evacuated from Afghanistan. In this case an external fixator was used to achieve primary bony healing (Figure 4) and this was followed by augmentation of the mandibular defect with a free bone graft (Figures 5 & 6).

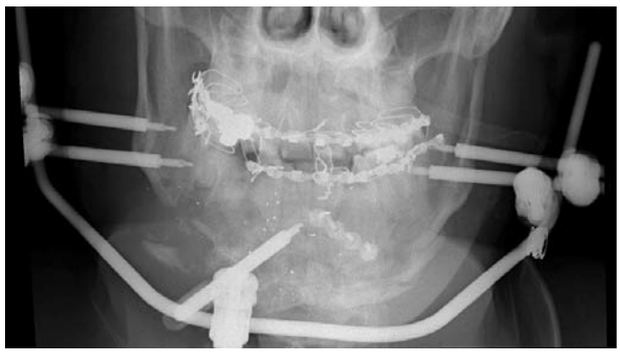

Figure 4: *Immediate post operative result with external fixator, mini plate osteosynthesis and arch bars*

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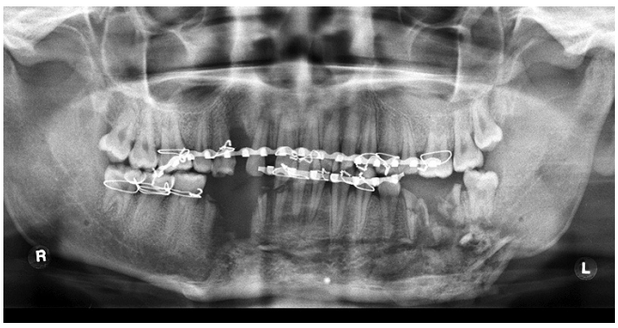

Figure 5: *Primary bone healing with limited residual bony defect*

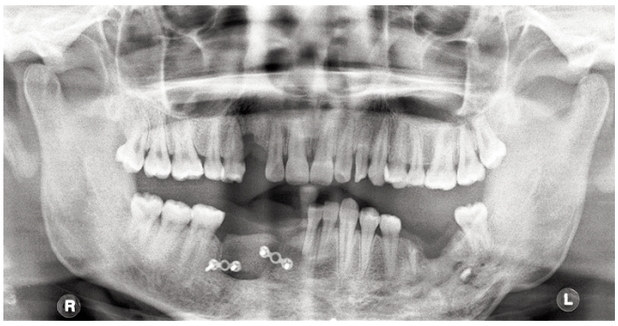

Figure 6: *Post bone graft to defect prior to dental implant placement*

The next stage will be placement of dental implants and prosthetic rehabilitation of the occlusion in the reconstructed mandible. By using these techniques and preserving tissue it has been possible to avoid the need for free tissue transfer which may not be possible if concurrent limb injuries limit donor site availability.

Case 3

This case demonstrates the use of distraction osteogenesis to create new bone at the site of injury. The initial mandibular injury was less comminuted than those previously described and was amenable to repair using contemporary osteosynthesis methods. Following primary healing there was a residual vertical bony defect with insufficient bone to place dental implants to restore the occlusion. The bone was osteotomised at the site of the defect and an internal distractor placed (Figure 7). After a short latent period this was activated and over the course of three weeks sufficient bone height was achieved to allow dental implant placement.

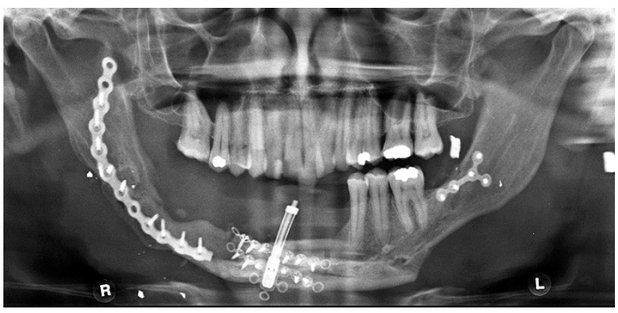

Figure 7: *Internal distractor in situ*

Despite careful pre-operative planning it is not always possible to predict the exact outcomes of such complex surgery and the final position of the dental implants was such that it was not possible to use them and further osteotomies were required to bring them into a functional position.

Case 4

Craniofacial and midface injures have been seen less commonly at UHB than mandibular injuries but are no less challenging. These injuries often require combined management with neurosurgical colleagues and the emphasis is on restoration of anatomic form so as to reduce functional disability and prevent infective sequalae. This case had a widely displaced nasal complex and zygomatic fractures in combination with supraorbital rim and frontal bone fractures (Figure 8). These injuries are best managed by open reduction anatomic reduction and fixation, and modern osteosynthesis equipment is ideal for this task (Figure 9).

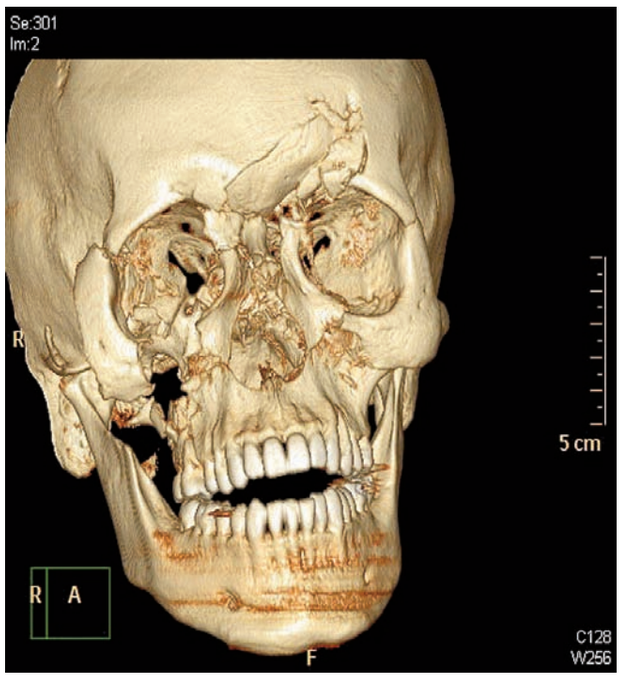

Figure 8: *3D CT demonstrating craniofacial injury*

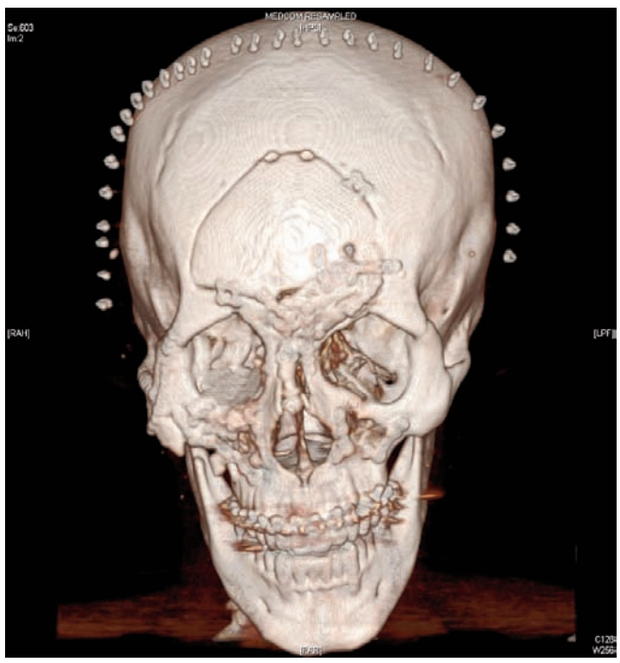

Figure 9: *3D CT demonstrating immediate post operative fracture reduction and fixation*

Excellent fracture exposure is achieved via a bicoronal approach, which also has the benefit of a well-hidden scar. One of the key features of the repair is the accurate reduction of the nasal bones of an associated medial canthal tendons to avoid post operative telcanthus which can be one of the more obvious post traumatic deformities.

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Conclusions

Warfare has long been recognised as a stimulus for advancing surgical and medical care. However treatment of maxillofacial injuries sustained in Afghanistan has required the use of both traditional and contemporary techniques to achieve the best possible outcome for wounded British servicemen evacuated to RCDM. As the experience of the maxillofacial team in managing these injuries develops, further refinements will undoubtedly follow but it is likely that there will always be a role for these traditional techniques.

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Lessons Learned in Oral and Maxillofacial Surgery from British Military Deployments in Afghanistan

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Abstract

This article describes the combined lessons learned from two deployments of a cadre of British Oral and Maxillofacial surgeons to Kandahar between July 2006 to April 2007, and September 2008 to April 2009.

Introduction

The British Oral and Maxillofacial Surgery Cadre have been deployed twice to the Role 3 multinational military hospital in Kandahar Afghanistan. Eight consultants deployed from July 2006 to April 2007, and five consultants, two of whom were accompanied by registrars, from September 2008 to April 2009. The British Military Oral and Maxillofacial Cadre holds 2 meetings a year at which cases are presented and experiences are shared. This article aims to outline the key surgical principles of oral and maxillofacial surgery as practiced in a conflict zone and to highlight some of the lessons learned by surgeons.

Work in the Role 3 Hospital

In the Role 3 hospital at Kandahar, all hospital staff are available on-call 24 hours a day. Clinical governance is implemented as it is in most developed nations' hospital systems. However, there is no need to meet targets and the ability to deliver patient centred care without Western hospital management restrictions is, for many clinicians, a rewarding experience. Nevertheless, difficult patient management decisions are required. Like all hospitals, there is finite bed and operating theatre resources meaning there is an emphasis on moving patients on through the chain of evacuation so that these resources can be kept available. Mass casualty situations occur regularly and place demands on both beds and theatre time. Elective operating is done early in the morning to free theatres for later in the day when new casualties arrive. Military patients are frequently evacuated within 24 hours of injury following resuscitation and stabilization in the hospital. Afghan patients are passed back into the limited national military and civilian hospital network when deemed appropriate. Approximately one third of patients are NATO or coalition personnel and contracted civilians, one third Afghan army and police and one third Afghan civilians.

Military maxillofacial surgeons may be required to have extended competencies in ophthalmic surgery and neurosurgery. Evisceration, enucleation or partial exenteration of eyes for penetrating trauma is frequently required. In addition, a good knowledge of paediatric maxillofacial trauma is important. Teamwork with colleagues is essential and joint operating, assisting or being assisted by other surgeons, is often necessary.

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Injury Patterns

A conflict zone hospital is a unique working environment. The challenges faced in treating military and civilian patients, including children, in a relatively austere environment should not be underestimated. Although surgeons can prepare by working in busy Western trauma centres, they will rarely treat blast or high energy transfer velocity ballistic injuries. The majority of ballistic injuries seen in the West are from low muzzle velocity hand guns. In recent military conflicts 75% of injuries are due to explosive mechanisms [1]. In the second Oral and Maxillofacial Surgery Cadre deployment in Afghanistan, over 50% of military oral and maxillofacial injuries were due to improvised explosive devices (IEDs) and the majority of gunshot wounds were from high energy rounds. Oral and Maxillofacial surgery patients with blast or other high energy transfer velocity injuries often present with extensive, contaminated soft tissue wounds and comminuted fractures. Tissue avulsion is frequently seen. Blast injuries may be further complicated by burns and multiple injuries both to the face and to other peripheral body sites. The use of body armour has led to a proportional increase in head and neck injuries [2].

Assessment

The Oral and Maxillofacial injury assessment should be a systematic and meticulous clinical examination between the top of the scalp and the clavicles. Frequently missed injuries are scalp lacerations, nasal fractures and small but deep penetrating shrapnel injuries. The penetrating and avulsive type of trauma seen is different to the blunt trauma seen in the West. A practical classification of wounds is to divide them into four groups (Box 1).

1. Soft tissue damage such as contusions, abrasions and lacerations.
2. Hard tissue damage i.e. fractures.
3. Soft tissue loss.
4. Hard tissue loss.

Box 1: *A classification for managing maxillofacial wounds*

This system focuses the surgeon's mind onto whether wounds can be closed primarily or whether the degree of hard and soft tissue loss means that later replacement and reconstruction is required. Any missing teeth should be accounted for as they may compromise the airway. Teeth lying in the airway adjacent to an endotracheal tube, buried in soft tissues or within the sinuses can be detected on CT scan.

The ready availability of CT scan with 3 dimensional reformatting improves clinical diagnosis. However, in Kandahar the patient is frequently passed from the CT scanner already intubated and into the operating theatre. It is important in the emergency setting to take time to methodically look through the CT scans before operating and record where shrapnel is and the precise sites and pattern of injury. In the finer bones of the midface, CT reconstructed images may fill in fractures that are undisplaced (Figures 1&2). Therefore, CT scans should not be relied upon alone and a thorough clinical evaluation of the common sites of fractures must be made prior to surgery. The assessment of the occlusion may be difficult in the orally intubated patient.

Initial Management

The initial management of facial injuries follows established military protocols. These protocols are similar to those of Advance Trauma Life Support [3] but differ in that the control of catastrophic, life threatening haemorrhage is dealt with first [4]. A cricithyroidotomy is the best way to establish a surgical airway in an emergency. A tracheostomy should only be done in theatres in a controlled environment and the flange sewn to skin to prevent dislodgement of the tube during evacuation. Maxillofacial haemorrhage is frequently stopped by local measures at the site of injury and temporary reduction and fixation of fractures. The face

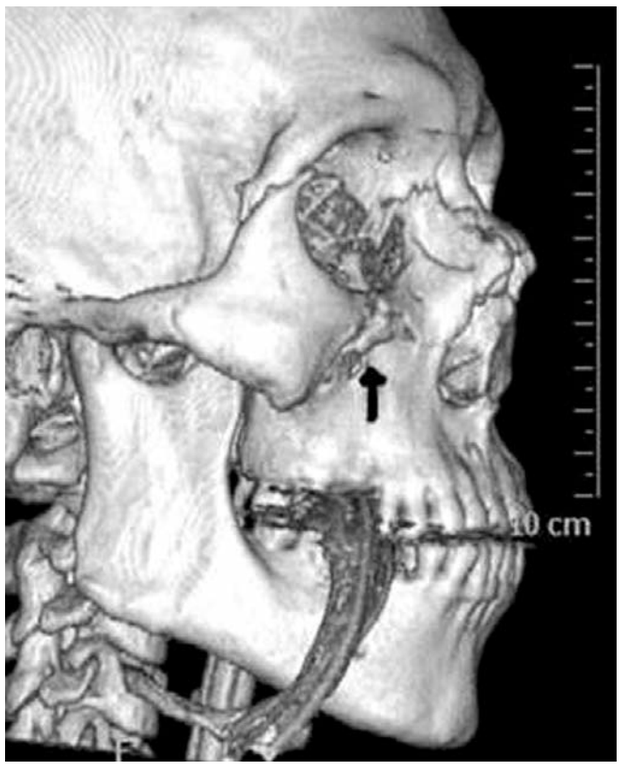

Figure 1. *Preoperative 3D CT image showing right zygomatic complex fracture (arrowed) orbital floor and nasal fractures.*

Figure 2. *Post-operative 3D CT image showing undisplaced Le fort 1 (fracture arrowed).*

is rarely the site of torrential haemorrhage sufficient to be the sole contributor to hypovolaemic shock. However, when this does occur ligation of the ethmoidal vessels or the external carotid artery may be required. Patients with maxillofacial ballistic injuries should have a low threshold for placement of a tracheostomy tube. The likelihood of later airway swelling, further operations in a compromised patient and the need to correctly position the occlusion without the interference of an oral endotracheal tube may all necessitate a tracheostomy.

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Once life saving measures have taken place, the patient requires resuscitation and initial surgical stabilisation [5]. The concept of damage control resuscitation and surgery applies to all severely injured oral and maxillofacial surgery patients and is vigorously applied at the Kandahar Role 3 Hospital. Damage control resuscitation aims to prevent the lethal triad of hypoxia, acidosis and coagulopathy by permissive hypotension and haemostatic resuscitation [6]. The goal of damage control surgery is to limit the physiological insult of surgery by carrying out the minimum amount of surgery in the shortest time to stabilize patients and prevent infection [7, 8]. Definitive surgery is done when the patient's condition has been optimized.

Oral and Maxillofacial Surgery

Early and aggressive debridement of wounds is required to prevent infection. This may involve the use of scrubbing brushes, pulsed lavage and copious irrigation. Surgical dermabrasion with a scalpel blade can be used to remove all debris that may cause subsequent wound tattooing which is difficult to correct. Deep penetrating wounds that are difficult to debride should be packed with iodine soaked gauze. To minimize unaesthetic scarring, superficial wounds that have been adequately cleaned are best closed primarily and rotation flaps may be used to close small defects. In high energy exchange ballistic trauma the wound is contaminated and the zone of tissue devitalisation around the missile tract will be unclear. These wounds should be cleaned and packed and serially debrided over several days until the vital wound margins have declared themselves [9]. Judgment is required to adequately clean the wound but not to strip vital periosteum or remove potentially viable tissue. In the early closure of soft tissue defects with rotational or advancement flaps thought should be given to possible later reconstruction if the flap breaks down. The rotational flap should not compromise the blood supply to a larger soft tissue flap. If it does it may be best to pack the area and close the defect once the tissues are seen to be clean and healthy.

Simple bony trauma can be repaired using conventional techniques of open reduction and internal fixation with craniofacial plates. However, caution must be exercised in using plates in contaminated wounds or wounds with associated large soft tissue defects. Primary reconstruction with bone plates and screws in the austere combat environment often yield poor results with subsequent soft tissue infections and plate exposures [10]. Inter maxillary fixation (IMF) using IMF bone screws [11] or arch-bars provide good reduction and often adequate immobilisation of mandibular fractures. Patients require wire cutters to be with them at all times to cut wire or elastics placed between the IMF screws or arch bars in case of vomiting which may compromise the airway. External fixators are robust and simple to apply. No foreign material is introduced at the fracture site and any soft tissue or bony defects may continue to be debrided with the fixator in place. External fixators are well suited to treated battlefield facial fractures and have been used frequently in Afghanistan. Combinations of plates, IMF, and external fixators can be used (Figures 3, 4 & 5).

Poor outcomes of ballistic facial injuries are often due to scarring and fibrous contracture in areas of severe tissue damage. Infection may have led to wound breakdown and increased the scarring and fibrosis. Regions of soft tissue avulsion closed over bony defects lack bone support and will contract, distorting the surrounding tissues. The resulting aesthetic and functional compromise may be severe. To optimise surgical outcomes, definitive surgery should be considered from the first operation. Infection must be prevented but wounds should be closed as early as possible to minimise scarring. Bones should be held in their correct position with IMF, external fixators or, where applicable, bone plates. Early bone repair should be done when all infection has been cleared and ideally within 3 to 4 weeks to minimize fibrosis and collapse of the soft tissue envelope [12].

NATO or western civilian personnel are evacuated back to their own Countries where reconstruction using free flaps, osseointegrated implants and prosthesis, or osteogenic distraction techniques may be considered. In the austere environment of Afghanistan reconstructive surgery for local nationals should be kept as simple as possible in order to obtain the best results. This may involve scar revision, rotational flaps and bone grafts.

Rehabilitation with adequate nutrition, good oral hygiene and physiotherapy is an important part of treatment. Tongue spatulas may be used between the teeth to stretch facial scars and prevent trismus (Figures 6 & 7).

Figure 3. *Preoperative 3D CT image showing severe ballistic complex comminuted facial fractures.*

Figure 4. *Treatment of mid-face fractures with an external fixator, intermaxillary fixation and mandibular palates.*

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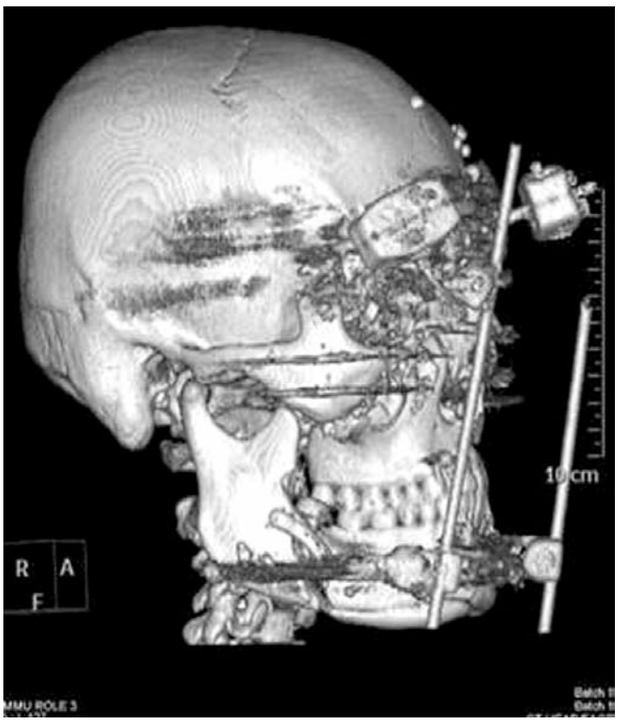

Figure 5. *Preoperative 3D CT image showing severe ballistic complex comminuted facial fractures.*

Figure 6. *Facial scarring leading to trismus.*

Figure 7. *Treatment with tongue spatulas to stretch scars and improve mouth opening.*

Body Armour and Measures for Facial Injury Prevention

The use of body armour has reduced the overall number of deaths and torso injuries but has increased the relative proportion of wounds to the extremities including the head and neck [2]. Oral and maxillofacial surgeons often saw patients with damaged protective glasses that had prevented penetrating eye injuries from shrapnel. Further work is needed on facial armour that can protect the face without limiting visual fields and mobility. In vehicles, soldiers on 'top cover' frequently present with blast injuries to their exposed faces. This particular group would gain maximum benefit from facial armour. Military personnel within troop carriers rarely wear seat belts as they may not fit over body armour and are thought to restrict rapid evacuation. Hence, when the vehicle is hit by an IED the soldiers are thrown around inside the vehicle and incur limb and facial lacerations and fractures. Quick release seat belts that are able to be fastened over bulky body armour would help prevent these injuries and this is an area of ongoing research.

Conclusions

The role of military oral and maxillofacial surgeons within the Role 3 Hospital at Kandahar is established. With the high workload, a wealth of experience in the management of ballistic trauma can be gained by surgeons in just a few months. Since returning from deployment the British Oral and Maxillofacial Surgery Cadre has held regular clinical meetings. From the knowledge acquired, several teaching initiatives have taken place. These include presentations on the Military Operational Surgical Training (MOST) course at the Royal College of Surgeons of England and for the Norman Rowe International Education Foundation work in post conflict countries. The MOST course is held over 5 days twice a year for military medical staff and aims to transfer skills between surgical specialities and give an update on current surgical techniques used in the management of battlefield trauma.

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