Management of maxillofacial injuries

Brian Swinson, Tim Lloyd

Maxillofacial injuries account for 5% of all acute attendances at accident and emergency units, and are often seen in the multiply injured patient. A systematic method of examining and investigating these patients is required for all staff involved with trauma patients and an understanding of the principles of their management will help to prioritize treatment needs.

Maxillofacial injuries presenting to accident and emergency (A&E) departments are on the increase, most commonly being the result of interpersonal violence, sports injuries and falls. They now account for 5% of all acute attendances at A&E (Hutchinson et al, 1998) with alcohol being a major contributing factor. Following the introduction of seat belt legislation in the UK, the number of cases caused by road traffic accidents has rapidly fallen, although the use of air bags in motor vehicles has lead to a different pattern of injury.

Injuries treated by the maxillofacial team range from minor soft tissue lacerations through to complex craniofacial trauma requiring a combined approach with neurosurgical colleagues.

PRIMARY EXAMINATION

Initial management of assessment and resuscitation should follow the Advanced Trauma Life Support guidelines.

Cervical spine injury should be suspected in all patients with blunt trauma above the clavicles and these patients should be immobilized, in a neutral position, in a semi-rigid collar until clinically and radiographically cleared. Cervical spine injury accompanies 5% of facial bone fractures.

During the primary survey there may be airway compromise as a result of blood, teeth or dentures being retained in the oropharynx or inhaled. Fractures of both the mandible and maxilla may both cause difficulty in maintaining the airway in addition to indicating severe supraclavicular trauma, increasing the likelihood of injury to the cervical spine. Cuffed orotracheal intubation is the desired method of securing the airway but the nasotracheal route may be indicated if the patient is conscious. Nasotracheal intubation should be used with caution in suspected fractures of the middle third of the facial skeleton. In severe cases, a surgical airway may be required; cricothyroidotomy is now preferred to the emergency tracheostomy as a short-term measure.

Haemorrhage from the face or scalp can be dramatic but can usually be controlled with pressure packs, sutures or tying off the offending vessel. Bleeding from a middle third fracture, however, can be much more occult, and difficult to control, with ligation of the external carotid artery occasionally being required. Epistaxis may also be encountered, requiring anterior or posterior nasal packing, although surgical shock is rarely a feature of maxillofacial injuries.

Level of consciousness, pupil size and reaction to light are all indicators of intracranial damage and these should be recorded as a baseline figure. Significant deterioration of the level of consciousness requires an early neurosurgical consultation. Traumatic optic nerve neuropathy may also cause pupillary asymmetry.

Following a full primary survey and resuscitation as required a secondary survey is instigated including a thorough maxillofacial examination.

MAXILLOFACIAL EXAMINATION

A systematic examination of the hard and soft tissues of the calvarium, face, dentition and cervical region is essential to fully assess the maxillofacial region. Starting with the scalp and calvarium diligent inspection of any lacerations, contour deformities or obvious haematomas is undertaken. Palpation for crepitus, depressed or penetrating skull fragments, or areas of tenderness should be carefully done.

Examine the whole maxillofacial area for asymmetry or obvious deformities. Look specifically for evidence of any CSF leaks either nasally or from the external auditory meatus. If doubt exists send a sample for beta-2-transferrin levels to confirm the diagnosis. Base of skull fractures should be suspected clinically if well-defined bilateral periorbital ecchymosis is present indicating anterior skull base, or Battle's

Mr Brian Swinson is Specialist Registrar in Maxillofacial Surgery and **Mr Tim Lloyd** is Consultant Maxillofacial Surgeon, University College Hospital, London WC1E 6AU

Correspondence to: Mr B Swinson

sign is present postauricularly revealing a middle cranial fossa leak (although this may be confused with blood tracking down from an intracapsular condylar fracture). The auditory canal should be examined for signs of haemotympanum or a laceration of the floor of the external auditory meatus caused by central dislocation of the condyle or a condylar fracture.

Systematic bimanual palpation of the entire facial skeleton is commenced at the supraorbital rims, zygomatico-frontal suture, infraorbital rims and medial canthal areas. Symmetry and prominence of both zygomatic arches and bodies should be compared, examining both from in front and above. Disruption or asymmetry of the nasal bone complex should be noted, looking particularly for septal haematoma which requires immediate drainage to avoid the complication of septal necrosis. Nasal air passages should be examined with a speculum to check for obstruction. Middle third fractures can be confirmed clinically by checking for mobility. This involves grasping the maxilla by the anterior alveolus and feeling for movement or elicited crepitus. This also gives an idea of the level of the fracture.

Gentle pressure at both mandibular angles may elicit discomfort, raising the possibility of a fracture, while the whole lower border is palpated for steps. Palpation of both temporomandibular joints at rest and with the mouth open will check for possible condyle fractures. Mouth opening and jaw movements should also be assessed (*Table 1*).

TABLE 1. Examination

Soft tissues	Extra-oral	Scalp
		Eyes
		Ears
		Nose
		Lips
	Intra-oral	Bruising
		Lacerations
Hard tissues	Cranium	
	Orbits	
	Nose	
	Zygomas	
	Maxilla	
	Mandible	
Dental	Teeth	Fractures
		Missing
		Dento-alveolar fractures

Ophthalmic examination is mandatory and should include visual acuity, direct and consensual light reflexes, papillary levels and the presence of enophthalmos, proptosis or hypoglobus. The presence of diplopia, pain or limitation of eye movement should also be noted as well as fundoscopic examination. The interpupillary and intercanthal distances should be measured (normal values 32–35 mm), as they may indicate a nasoethmoidal problem, and epiphora may reveal damage to the lacrimal system. Urgent surgical exploration is indicated if there are signs of muscle entrapment in the paediatric patient with an orbital floor fracture.

Intra-oral examination should document all teeth present, note any absent or fractured teeth and check for any occlusal derangement. Segmental alveolar fractures should be noted as well as any sublingual haematomas or gingival lacerations. Full inspection of the palate, floor of mouth and tongue should be carried out and any lacerations noted. Palatal haematoma indicates a maxillary fracture which may be confirmed by percussing the upper teeth and listening for a 'cracked cup' note. Sensation of the entire face should be checked bilaterally and all cranial nerves formally examined (*Figure 1*).

RADIOLOGICAL INVESTIGATION

Good quality plain radiographs, taken in two planes at 90° to each other, provide the cornerstone of imaging in maxillofacial injuries. Their aim is to confirm the clinical impression and formulate a diagnosis. These may be difficult to obtain in an uncooperative patient or at night in the A&E department, and if surgery is not indicated immediately they can usually be postponed until the patient is more forthcoming.

Figure 1. Retrobulbar haemorrhage with proptosis, subconjunctival haematoma and ophthalmoplegia. The patient had a painful blind eye.

For suspected mandibular fractures, essential views are the orthopantomogram and the posteroanterior of the mandible. These can be augmented with lateral oblique views and dental periapical and lower occlusal films. A reverse Towne's view provides good information if a condylar fracture is suspected.

Imaging of suspected middle third injuries should be by 10° and 30° occipitomental views and a lateral facial film. Waters' view to image the orbital floor has now largely been superseded by computed tomography (CT) scans. Submentovertex films are useful in isolated zygomatic arch fractures. Many simple nasal fractures do not require radiographs as they add little to the clinical diagnosis. Standard cervical spine views should be mandatory in all suspected middle third fractures.

Figure 2. Computed tomography evaluation with axial, coronal and parasagittal views. Three-dimensional computed tomography reconstruction aids preoperative treatment planning.

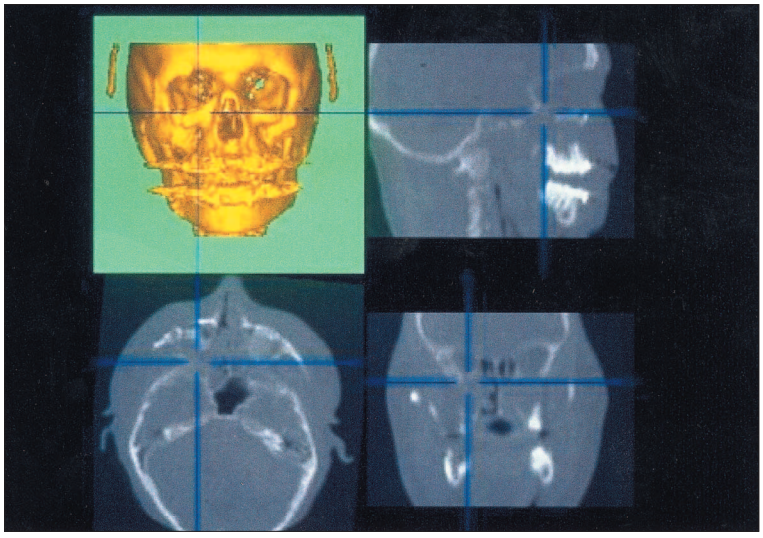


TABLE 2.
Useful radiographs

Mandibular fractures	Postero-anterior of lower facial bones
	Orthopantomograph
	Lateral oblique
	Dental occlusal views
	Modified reverse Towne's
Upper and middle third fractures	Occipitomental 10° and 30°
	Posteroanterior facial bones
	Submentovertex
	Lateral facial bones
	Skull views
	Cervical spine views

Dento-alveolar injuries will require periapical or occlusal views.

Computed tomography scanning

CT scanning has now become more widely used in the management of acute severe maxillofacial injuries because of increased accessibility and formatting. The bony detail provided by spiral CT scanning is excellent and proves invaluable in assessing severely comminuted mid face injuries, being particularly useful in suspected nasoethmoidal and orbital injuries where fine cut 0.5 mm slices with coronal and sagittal reconstructions provide excellent imaging of the injury.

Three-dimensional reconstruction and stereolithography are being increasingly used. Stereolithography provides a 1:1 resin model of the injury from a three-dimensional CT scan on which surgery can be planned or an implant prosthesis constructed (*Figure 2*).

Magnetic resonance imaging

Magnetic resonance imaging is rarely used in the acute setting of maxillofacial trauma but can be helpful in assessing orbital contents and intracapsular injuries to the temporomandibular joint. It is also of use in evaluating associated CSF leaks and has a role in imaging vascular injuries of the head and neck (*Table 2*).

TREATMENT

Principles of treatment

As with all trauma, diagnosis and treatment planning is the cornerstone of the management of facial trauma. It has been suggested that the timing of surgery is important as the earlier fractures are reduced and immobilized the lower the chance of infective complications occurring. Later repair is associated with poorer outcomes and residual defects which are very difficult to correct. However, early treatment is often hampered by swelling, making accurate reduction and assessment of symmetry difficult.

There are essentially two windows of opportunity for management: early or delayed. Treatment may be delayed because of other more life-threatening injuries or to allow swelling to subside. Emergencies should be operated on immediately. Maxillofacial emergencies include airway problems, uncontrollable haemorrhage or vision-threatening injuries which include retrobulbar haemorrhage, direct optic nerve injury or penetrating eye injuries. All fractures through the tooth-bearing bone are open and compound to the mouth and ideally should by treated within 24 hours. With panfacial and midfacial fractures it may be beneficial to allow the oedema to

resolve before treatment, while zygomatic and orbital floor injuries may wait for 7–10 days.

Antibiotic prophylaxis should be instigated according to the likely contaminants. All mandibular fractures are contaminated with a mixed aerobic and anaerobic flora and the combination of metronidazole and a penicillin is advised. Gross comminution of the fronto-nasoethmoidal area, particularly if CSF rhinorrhoea exists, requires eradication treatment directed against the commensal agent responsible. Early treatment with intravenous dexamethasone may be used to reduce orbital and floor of mouth swelling. Tetanus prophylaxis may also be required.

Soft tissue injuries

The head and neck region, especially the face, has an excellent blood supply which enables conservation of contused and contaminated tissue that would require debridement in any other area of the body. Excision of wound edges and debridement of doubtful tissue can therefore be kept to a minimum, although meticulous cleansing of the wound with a scrubbing brush is essential if tattooing with road dust, for example, is to be avoided. Many apparently gaping wounds can be approximated easily without tension or distortion of the surrounding structures. It is important to establish the presence of tissue loss as failure to do so may result in inaccurately approximated edges and distortion of important areas, e.g. nose, vermilion border or eyelids, the latter causing particularly unsightly ectropion. Soft tissue radiographs may be required to identify retained glass and wood can be diagnosed on ultrasound.

An understanding of the underlying anatomy is needed to assess possible damage to underlying structures, for example facial nerve, parotid duct or nasolacrimal system. Damage to these structures requires formal exploration and reconstruction using microsurgical techniques.

Areas of tissue loss require local flaps or grafts. For delayed grafting split skin grafts may occasionally be used as a temporary measure on the face but their poor colour match and subsequent contraction make them unsuitable for definitive repair. Full thickness grafts offer a better cosmetic result and can be harvested from post auricular, supraclavicular or forehead sites, although they need a clean well-vascularized bed for a successful augmentation. Primary repair with later planned scar revision is also used, especially with eyelid and ear lacerations.

A cooperative patient, good lighting, correct suture choice and meticulous technique are prerequisites to a good aesthetic outcome.

HARD TISSUE INJURIES

Dental injuries

Dento-alveolar trauma comprises injuries which are limited to the teeth and supporting structures. They may occur in isolation or in combination with other facial injuries. They are most commonly encountered following interpersonal violence, falls, cycling accidents or contact sports, with children and adolescents being the main demographic group.

Intra-oral examination is mandatory in all patients presenting with facial injuries and unsuspected dento-alveolar injuries are commonly missed if this protocol is not adhered to.

Examination of the occlusion and accounting for each tooth in the dental arch is carried out and documentation of any chipped, cracked, subluxed or missing teeth is made. The patient or relatives should be asked about the whereabouts of chipped portions or missing teeth. These may be at the scene, lodged in soft tissues, swallowed or inhaled. If they cannot be found a chest radiograph may be needed to eliminate the possibility of inhalation.

Patients with avulsed teeth found at the scene should attempt immediate reimplantation or be advised not to handle the root, to gently rinse off debris and to transport it in milk immediately to the casualty department for reimplantation and splinting by the resident dentist.

Independent mobility of segments of the alveolus containing several teeth confirm an alveolar fracture that may require temporary splinting to provide analgesia. The management of these injuries is best left to the maxillofacial team where they will be included in the total treatment plan.

FACIAL FRACTURES

Principles of management

Revolution has occurred over the past 20 years with the development of better surgical access and fixation techniques causing minimal morbidity. Endoscopic techniques for surgical access are also being developed. The majority of facial fractures are now treated using open techniques.

Treatment methods are similar for most of the facial skeleton, although they may differ in relation to the prevailing stresses on the bones concerned. Whichever area of the facial skeleton is to be treated, the basic rules (Rowe and Williams, 1994) should be followed:

- Anatomical reduction
- Stable internal fixation
- Atraumatic technique
- Early mobilization of the jaw
- Rehabilitation.

Early consultation with anaesthetic colleagues is required so the method of intubation may be

determined and any early postoperative complications predicted and avoided. Naso-endotracheal intubation is often required and may need fibre-optic assistance.

Fracture classification

The bones of the facial skeleton vary considerably in thickness and strength. They range from the dense lower mandibular border to the paper-thin ethmoid bones. Large forces can be withstood if they are directed along the strong buttress areas of the facial skeleton but obtuse forces are poorly resisted and cause fairly predictable patterns of fractures because of the juxtaposition of thick and thin bones, the fracture taking the path of least resistance.

The facial skeleton is divided conveniently into three areas:

1. Upper third – comprising the calvarium and frontal bones
2. Middle third – comprising all hard tissue from the upper occlusal plane to the supra-orbital ridges
3. Lower third – comprising the mandible and lower dentition.

These fractures may be classified as open, closed or complicated and again as greenstick, single, multiple or comminuted.

Fractures of the lower third (mandible)

Signs and symptoms: Derangement of occlusion, often with a step deformity, pain, crepitus, gingival laceration, sublingual haematoma and sensory deficit of the lower lip. Condylar fractures may be associated with deviation on opening if unilateral or an anterior open bite.

Management: The main aim of management is accurate restoration of occlusion and rehabilitation of pre-injury function. Reduction can be achieved manually and immobilization by various methods. Modern management uses direct osseosynthesis with miniplates (Ward Booth et al, 1999). The plates are applied along Champy's designated lines of tension (Champy et al, 1978), one plate usually being sufficient posterior to the mental foramen and two anteriorly to counteract rotational torque. Plate placement can usually be achieved intra-orally, although occasionally this may require a transbuccal trocar.

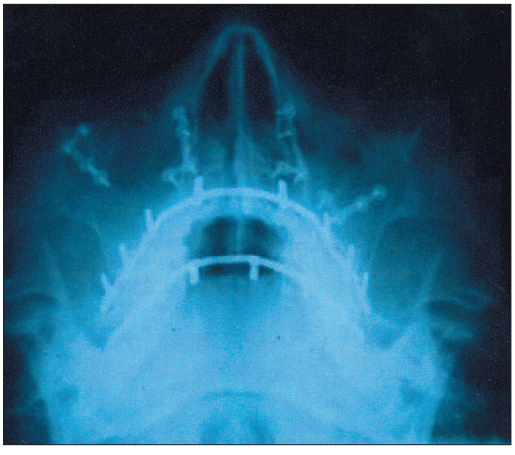


Figure 3. Postoperative radiograph revealing multiple miniplates and archbars used to manage a middle third fracture.

Management of condylar fractures raises much debate although the choice is usually between conservative management or open reduction and internal fixation via an extra-oral approach. The protocol differs depending on whether uni- or bilateral or whether an adult or paediatric patient. Endoscopically-assisted approaches to the condylar area are gaining increasing popularity.

Edentulous mandibular fractures have been historically treated with modified dentures or Gunning splints but plating, K-wiring and onlay grafting all have been used to good effect. The aim is to achieve bony union and to allow dental rehabilitation. The use of large reconstruction plates has been suggested, however, this impedes future dental rehabilitation. A more physiological approach is to use a split rib graft to splint the fracture (*Figure 3*).

Fractures of the middle third

Classification of fractures in this area encompasses zygomatic, orbital and nasoethmoidal injuries in addition to the classic Le Fort levels I–III. The Le Fort patterns of injuries are relatively uncommon as they follow a low energy impact, while most injuries are high energy trauma causing gross comminution.

- The Le Fort I fracture is at a low level detaching the maxillary alveolus and palate. The fracture passes through the nasal septum, lateral nasal wall and maxillary sinus walls.
- The Le Fort II or pyramidal fracture passes through the lateral antral walls, infraorbital margins, nasal bones and medially above the nasal aperture.
- The Le Fort III fracture presents with craniofacial dysjunction as the fracture passes through frontonasal sutures, orbits and zygomaticofrontal sutures and detaches the facial skeleton from the underlying skull base.

These injuries may occur in combination, i.e. Le Fort II on the right with a Le Fort I on the left, and tend to occur in low velocity injuries. High-energy impacts tend to cause extensive comminution which does not follow the above patterns.

Signs and symptoms: Middle third injuries present with 'dish-faced' deformities accompanied with gross facial swelling and bilateral periorbital haematomas ('raccoon

eyes'). Subconjunctival haemorrhage with no posterior limit, enophthalmos, telecanthus or hypoglobus point to disruption of the bony orbital walls. Severe epistaxis may be present requiring anterior or posterior packing and the clear tracks of CSF rhinorrhoea should be sought. Posteroinferior displacement of the maxillary segment produces the dish-faced deformity but also causes the posterior teeth to bite prematurely, giving an anterior open bite. Upper dental percussion may produce a dull cracked cup note and paraesthesia of the infraorbital nerves may also be present.

Isolated orbital floor injuries present with swelling, bruising, diplopia and limited movement on upward gaze, enophthalmos being a late sign following resolution of oedema. A forced duction test is used to demonstrate limited orbital movements while under general anaesthetic. This injury can be seen in conjunction with a zygomatic fracture where these signs and symptoms will accompany subconjunctival haemorrhage, step deformity of the infraorbital rim, paraesthesia of the infraorbital and upper anterior gingival areas, and trismus.

Management: In the management of Le Fort type injuries the aim is to align accurately the dental occlusion with reference to the intact mandible and to restore the correct anteroposterior (AP), vertical and lateral dimensions of the facial skeleton. Historically this was achieved by either the use of internal suspension or external fixation. With internal suspension, wires are passed through the soft tissues from remote fixed bony points, to suspend the reduced bones in a stable position. External fixation immobilized the reduced middle third between the mandible and the skull base and immobilized it with fixators, e.g. Royal Berkshire halo frame or the Mount Vernon box frame.

These methods have now been superseded by opening all fractures, anatomical reduction and immobilization with miniplates, low-profile miniplates or microplates. Arch bars are often secured to the teeth and light elastic intermaxillary fixation may be required temporarily to ensure a perfect occlusion.

Access to the middle third of the facial skeleton may be achieved through several approaches. Intra-oral upper gingival incision may be sufficient for Le Fort I type fractures but for access to infraorbital, nasofrontal and zygomaticofrontal regions an extra-oral approach is required. These can be achieved via medial canthal, transconjunctival, subtarsal, second crease or upper or lower blepharoplasty incisions. Where extensive exposure is required in grossly comminuted fractures, the bicoronal incision offers excellent access with minimal morbidity.

Zygomatic fractures are usually reduced by temporal, percutaneous or intra-oral approaches. The Gillies temporal (Gillies et al, 1927) approach involves an incision within the hairline and passing an elevator deep to the temporal fascia to get below the zygomatic bone. A bone hook can also be passed percutaneously under the prominence and easily elevated. The Keen (1909) intra-oral approach is also used and achieved through an upper buccal incision. Once the zygoma has been elevated its stability is tested and, if unstable, open reduction and internal fixation are indicated. Fixation usually requires miniplates to be placed at the zygomaticofrontal, infraorbital and maxillary buttress areas or occasionally K-wiring through the zygomatic bone (Ellis et al, 1985).

Orbital floor fractures may be 'pure' if the infraorbital rim remains intact or 'impure' if not. These fractures may cause tethering of the orbital contents, usually Lockwood's suspensory ligament, the inferior rectus muscle or fat, in the fracture line and so must be explored to release the entrapment and to reconstitute the orbital floor. The latter is achieved either with autologous or alloplastic grafts. Calvarial or maxillary bone, septal cartilage being commonly used or artificial materials, e.g. bioresorbable polydioxanone (PDS; Ethicon Inc, Somerville, USA) or Medpore (polyethylene) sheets (Porex Surgical Products, Newman, USA) (Gruss, 1995). Custom-made titanium plates constructed on a stereolithographic model are now gaining favour.

Fractures involving the nasoethmoidal complex require meticulous reconstruction of the bony medial walls of the orbit, nasal bones, medial canthal and lacrimal apparatus (Poole and Briggs, 1989). Failure to correctly restore the pre-morbid relationship will result in unsightly telecanthus (distance >35 mm between medial canthi) which is almost impossible to correct at a later date (*Figure 4*).

Fractures of the upper third

Signs and symptoms: Ecchymosis, flattening of the nasal bridge, CSF rhinorrhoea and obvious deformity of the calvarium or frontal sinus area.

Management: Access to fractures of the frontal sinus, orbital roof, nasoethmoidal and calvarial areas is best achieved via a bicoronal flap unless there is a pre-existing laceration. These injuries are usually treated jointly between maxillofacial and neurosurgical teams.

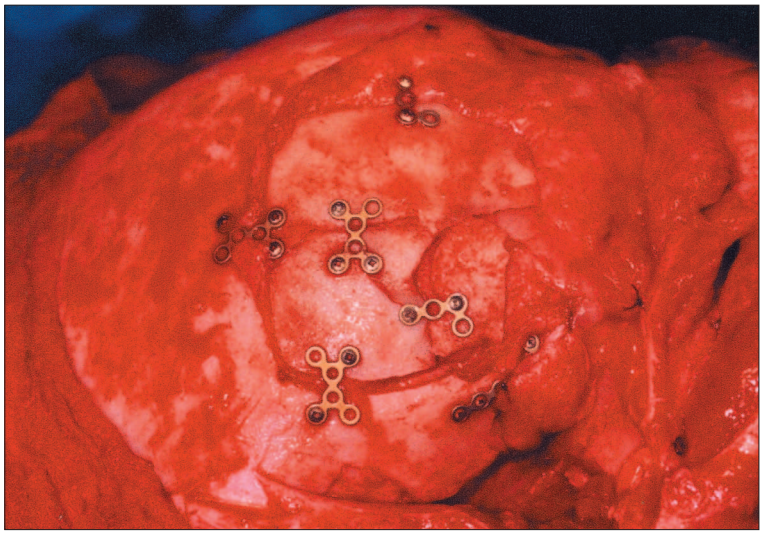
With frontal sinus fractures it is important to establish whether the injury involves both anterior and posterior walls or just the anterior. Anterior

wall defects present with a cosmetic defect and should be restored with reduction and internal fixation of the bony segments. Fractures which involve both walls present a different challenge. Disruption of the frontonasal duct may lead to potentially life-threatening complications, i.e. mucocele, mucopyelocele, meningitis and cerebral abscess (Gerbino et al, 2000). The options are:

- Obliterate the duct, remove the sinus mucosa and obliterate the sinus with bone or fat or muscle plus reconstruction of the anterior wall
- Cranialization of the sinus, removal of the posterior wall, sinus mucosa removal and covering the sinus floor with a pericranial flap to act as a barrier between the anterior cranial fossa and nasal cavity. Anterior wall reconstruction should follow.

With either option it is important to carefully monitor these patients on long-term follow-up for the development of any of the stated complications (Smoot et al, 1995).

Figure 4. Excellent access is obtained through a bicoronal incision for upper third fractures. Reduction and plating of frontal sinus fracture.



KEY POINTS

- Maxillofacial injuries account for 5% of all acute attendances in the accident and emergency department.
- Facial injuries are commonly missed in the polytrauma patient and require a high index of suspicion.
- Primary management should follow advanced trauma life support principles.
- Cervical spine injuries often accompany severe facial fractures and must be cleared clinically and radiographically.
- Thorough clinical examination and plain radiographs in two planes are usually sufficient to establish the diagnosis.
- Management principles of anatomical reduction with stable internal fixation and early rehabilitation apply.
- Each third of the facial skeleton has different requirements and treatment protocols have been developed accordingly.

FUTURE DEVELOPMENTS

Exciting developments are evolving in imaging, techniques and materials in the assessment and management of facial trauma. The rapid developments in quality and reconstruction of spiral CT images now allows very accurate demonstration of all facial injuries and, coupled with intraoperative scanning to assess accuracy of reduction (Stanley, 1999), provides vital information to the surgeon.

The development of sub-mental endotracheal intubation where the tube is brought out under the chin has allowed unimpeded access to the whole facial skeleton in complex cases. Endoscopic approaches are now being used to improve access to condylar fractures and the development of bioresorbable plating systems (Suuronen et al, 2000) offers exciting possibilities in the management of paediatric trauma. Bone morphogenic proteins are also being incorporated into plates to avoid the need for grafting in certain circumstances.

The development of distraction osteogenesis, now widely used in congenital deformities, is also being used in the late correction of secondary defects (Maull, 1999). HM

Conflict of interest: none.

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