A BACKGROUND TO THE MANAGEMENT OF COMMINUTED FRACTURES
OF THE MANDIBLE

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PREFACE

The term "comminuted fracture of the mandible" conjures up thoughts of extreme violence. It is in fact an injury that one associates with 'weapons of war', although there are many other causes for this type of fracture, for example the motor vehicle accident.

In discussions on fractures of the mandible the topic of "comminuted fractures" invariably arises. What do we mean by this term? How does it affect the management of our patient? What particular points in treatment differ from the usual approach to mandibular fractures? These and many other questions arise in the mind of colleagues who are presented with patients who have sustained a comminuted fracture of the mandible.

This treatise is primarily concerned with dispelling misconceptions related to the use of this term. The term "comminuted fracture of the mandible" tends to have been loosely used and poorly understood, so it is the aim of this thesis to put the whole topic of comminuted mandibular fractures into a correct perspective.

As the thesis developed the paucity of original work in the literature became increasingly apparent. Much has been written in general terms on maxillo-facial injuries but articles on the management of comminution which might have proved illuminating for those studying and working in the field of maxillo-
facial injuries have been found to be few in number. That there is now a great need for more detailed accounts and analyses of particular aspects of these injuries is evident and it is hoped that this thesis will help to fill the vacuum which presently exists in the literature and be a significant contribution to current knowledge.

The thesis is not intended to be a technique manual but a presentation of background knowledge that will contribute to a more complete understanding of the injured patient who has sustained a comminuted fracture of the mandible. It covers the management of comminuted fractures of the lower jaw and related subjects. The word 'management' is significant as it implies complete treatment of the injured person. Treatment of the fracture itself is considered only as part of the overall patient care. To this end, an introductory chapter concerns itself with the immediate care of the acutely injured patient. Other chapters deal with the care of injured soft tissue and the nature and behaviour of bone as an introduction to bone grafting (experimental and clinical) which may be necessary in the treatment of comminuted injuries. Prevention and treatment of post-operative complications are also dealt with as is incidence, aetiology and current trends in fracture management.
ACKNOWLEDGMENTS

The author is profoundly grateful to Mr. G. Stacy for his assistance, advice and encouragement in the preparation of this thesis. I would also like to thank Miss. B. Bischoff for the preparation of photographs.
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IMMEDIATE CARE OF THE ACUTELY INJURED

A comminuted fracture of the mandible as a rule
does not constitute a grave emergency, however, it may
be associated with other injuries that threaten life.
Thus, it is essential that the oral surgeon understands
the medical and surgical care of the acutely injured
patient. Frequently this patient will require the
services of more than one medical or surgical specialist.
The oral surgeon is an integral part of this specialist
team and may be called upon to participate in some
aspects of emergency care.

1. Priorities of Treatment - general discussion

The immediate care commences with the examination:

a) The initial examination (general and regional)
b) Subsequent examinations

The initial examination involves a quick but careful
perusal in order to establish priorities of
treatment. It is axiomatic that life saving
procedures are attended to first. The American
College of Surgeons Committee on Trauma (1965, p5)
states "A quick survey of the patient is made with
a view to doing first things first, noting

a) state of consciousness
b) airway and respiration
c) heart action
d) active bleeding
e) evident shock without obvious bleeding."
In the immediate post-traumatic phase the primary concern must always be for the patient's general medical condition. No local treatment of the fractures should be undertaken at this stage unless it has direct bearing on the elimination of respiratory embarrassment, control of haemorrhage or alleviation of shock (Richards, 1950). Irby (1969) maintains, that after immediate life saving procedures are attended to viz.,

- Airway (obtaining and maintaining a patent airway)
- Haemorrhage (control of bleeding and blood loss replacement)
- Shock (treatment for shock instituted)

care should be directed to a group of injuries classified as urgent,

ie

- Head
- Body
- Extremity injuries

A comminuted fracture of the mandible will rarely require treatment before other severe injuries, however, in the multiple injury patient surgical judgement may dictate that facial injuries be treated in conjunction with other body injuries. This is not usual and as a rule elective surgery within twenty-four hours after severe injury is hazardous and can rarely be justified. There are two important reasons for this:
1. It compromises the patient's welfare because of possible hidden head and body injuries.
2. It can lead to unsatisfactory treatment because of insufficient time available for adequate diagnosis and planning.

Deaths which occur under treatment are usually the result of injudicious and ill-timed operative procedures carried out upon a severely injured patient which should have been deferred until recovery from the initial effects of the injury had taken place (Rowe & Killey 1968, p224)

Rarely in the early treatment of the severely injured, in particular the multiple injury, is there time for a detailed history and examination. This is not intended to minimise the importance of obtaining a complete history but rather to emphasize the importance of life saving procedures. A patient in acute shock or unconscious from a head injury is unable to give a history. A history of the accident and the patient's clinical condition at the time of injury and subsequently should be obtained from the ambulance crew or a witness. At the same time as the initial examination the oral surgeon can briefly examine the facial injury (regional examination). Later, after all emergency procedures are complete and the general medical condition permits, a detailed clinical and radiographic
examination of the regional injury is undertaken.

Jones and Shires (1969) divide treatment into three groups according to priorities:

1. Injuries that interfere with vital physiologic function

2. Injuries that offer no immediate threat to life

3. Injuries that produce 'occult' damage.

Group 1. includes severe injuries resulting in airway obstruction, or massive internal or external haemorrhage. Patients within this group may require urgent surgery within five to ten minutes. The primary treatment being the establishment of an effective airway, blood loss replacement and control of bleeding. The avulsed symphysis and associated collapsed tongue is an example of a lower jaw injury that may give rise to airway obstruction.

Group 2. includes those patients whose 'vital signs' are stable. The majority of patients fall into this category and as a rule may require surgery within one to two hours, but if necessary it may be delayed for additional information to be obtained eg. radiographs, typing and crossmatching of blood etc.

Group 3. includes those patients who may or may not require surgical intervention and the exact nature of their injury is not always apparent.
Usually there is time for extensive laboratory studies, radiographic examination and physical examination. Surgery may be delayed for hours or even days.

A comminuted mandibular fracture cannot be considered as a hidden or 'occult' injury as its diagnosis can be readily established from careful clinical and radiographic examination of the patient. However, in the presence of any jaw injury one must be alerted to the possibility of an 'occult' head injury. It is imperative that this injury is diagnosed as early as possible so that if necessary, prompt life saving treatment can be initiated.

2. The Airway

a) Establishment and Maintenance of an effective airway.

"Failure of oxygenation of the blood in its passage through the lungs produces hypoxaemia. This constitutes a medical emergency which may occur with such disastrous speed that, unless urgent and effective treatment is started at once, brain damage, cardiac arrest and death will rapidly supervene" (Feldman and Ellis 1967, p12). The first and most important emergency procedure in the immediate resuscitation of an injured patient is the establishment of an effective airway.

Respiratory embarrassment takes precedence over
all other injury as anoxia will be fatal in a matter of minutes. It cannot be too strongly emphasized that comminuted fractures of the mandible, because of their very relation to the upper respiratory tract, may constitute a threat to life unless maintenance of the airway is assured. According to Rowe and Killey (1968, p226) there are four factors upon which an effective airway depends:

1) The absence of any anatomical or mechanical barrier
2) The preservation of the laryngeal reflex
3) The existence of adequate pulmonary ventilation
4) The integrity of the respiratory centre

Anatomical or mechanical obstruction to the inhalation of air is particularly relevant to injuries of the maxillo-facial region. There are three principle causes of this type of obstruction:

1) Inhalation and retention of nasal secretions, blood, vomitus, bone, teeth and foreign bodies
2) Occlusion of the oropharynx from posterior displacement of the tongue following loss of anterior support after comminution at the symphysis, the area for attachment of the genioid muscles. This may also occur following gunshot injury with tissue avulsion or when fragments override.
3) Retroposition of the maxilla with impingement of the soft palate against the posterior pharyngeal wall. The downwards displacement can cause occlusion of the oral airway by the soft palate resting on the tongue.

These complications can be prevented by mechanical and postural means. An effective posture is to place the patient on his side with the trachea inclined slightly downward and the mandible drawn forwards and the neck extended. In this way the tongue falls forward and drainage occurs away from the respiratory tract. This position is obligatory for the injured 'unconscious patient', as, on occasions, there is depression of the 'cough reflex' with subsequent aspiration of blood and oro-nasal secretions. Lying the patient in the supine position may seriously jeopardise the airway, presenting considerable risk of suffocation particularly during transportation to hospital. This applies particularly when the tongue lacks anterior support.

Obstruction must be relieved immediately and the fractured bones or disorganised tissues should be adjusted so as to assure an adequate airway. This may require temporary stabilisation of bone fragments and attention to displaced soft tissue.
It is also essential to examine the oral cavity and pharynx in order to remove blood clot, tenacious mucous and dental fragments. Wall or portable suction must be available in the ambulance and in the casualty or emergency room to remove pulmonary secretions, and other obstructions in the upper respiratory tract.

**Artificial Airway**

There are three basic methods of establishing an effective airway:

1. Endotracheal intubation
2. Tracheostomy
3. Laryngotomy (crico-thyrotomy)

Lloyd (1971) states "that an endotracheal tube in an unconscious patient is obligatory in order to secure the airway and allow a route for added oxygen. Further damage to the brain and vital centres may be minimised if this is performed at an early stage".

Endotracheal intubation according to Jones and Shires (1969) "is the most rapid method of obtaining an adequate airway". However, the mere presence of an endotracheal tube does not infer that the airway is 'adequate', for several reasons:

1. Occlusion of the tube by blood and mucous
2. The presence of a 'kinked tube'
3. Over-insertion of the tube lodging into the right bronchus inflating only one lung
4. Defective tube

5. Obstruction distal to the tube as in bronchospasm or pneumothorax.

Therefore a continuous watch must be placed on the patient during the immediate post-traumatic phase, and the tube aspirated at short intervals. When there exists anatomical or mechanical obstruction to endotracheal intubation, it is obviously not the most 'rapid' method of establishing an effective airway. Under such circumstances emergency laryngotomy (crico-thyrotomy) is the most rapid procedure, later to be followed by tracheostomy. However, a foreign body causing obstruction will ultimately require removal by bronchoscopy.

"Tracheostomy is amongst the most ancient of surgical operations yet until recently, it was regarded only as a last desperate procedure in upper respiratory obstruction. Today the indications for its use in the emergencies are wide and cover the whole range of causes of ventilatory failure" (Feldman and Ellis, 1967, p38).

The choice between an endotracheal tube and tracheostomy has aroused much controversy in recent years. According to Lloyd (1971) "In Oxford we have found it valuable to adopt the following policy:
1) Emergency tracheotomies are never performed. An endotracheal tube is always passed in the first instance.

2) If the patient remains sufficiently unconscious as not to object to the endotracheal tube, it is left in situ for an indefinite period. If the patient objects to the tube but still needs tracheal intubation, as in the case of a severe chest injury, a tracheotomy is performed. The purpose of tracheostomy is to prevent asphyxia by making an opening in the trachea to ensure breathing below an obstruction in the trachea or larynx.

There are four broad indications for tracheostomy:

1. Obstruction of the upper respiratory tract.
2. To enable artificial ventilation by mechanical means.
3. Aspiration of bronchial secretions that otherwise are difficult to remove.

Rowe and Killey (1968, p228) adopt a more specific approach, and divide indications into three groups:

- Immediate
- Intermediate
- Late

Tracheostomy should be performed immediately when there is:
1. Lack of tongue control (eg. comminuted symphysis)
2. Gross retroposition of the middle third
3. Actual or potential oedema of the pharynx and glottis

4. Uncontrollable oro-naso-pharyngeal haemorrhage
5. Respiratory inadequacy (pulmonary or C.N.S.)

Intermediate:
6. Essential immobilisation of the jaws with inadequate nasal airway
7. Inadequate post-operative supervision

Late:
8. Essential immobilisation of the jaws with pulmonary complications.

Kwapis (1954) stressed the value of judicious tracheostomy in reducing mortality. He has shown that suffocation may cause death within minutes in patients with extensively avulsed or comminuted fractures, especially in the region of the mandibular symphysis. He also feels tracheostomy is often indicated in deep penetrating wounds of the mouth and the base of the tongue. Haematomas may form in these regions, producing respiratory embarrassment without evidence of gross injury, an important point that is not included among the indications offered by Rowe and Killey.
Indications for tracheostomy are accentuated by the presence of head injury. When the patient is unconscious, in conjunction with severe injury to the chest or jaws, a tracheostomy is positively indicated. A point to be emphasized is that the majority of jaw injuries do not require tracheostomy before operation, even though intermaxillary wiring is used. However each case must be assessed on individual merit. Certainly severe gross injury to the jaws require a pre-anaesthetic tracheostomy.

Patients having sustained a comminuted fracture of the mandible appear to fall into three groups:

1. Those requiring no special precautionary measures such as posture, oropharyngeal toilet, suction and stabilisation of bone and displaced soft tissue.

2. Those requiring special precautionary measures such as posture, suction and oropharyngeal toilet and stabilisation of bone and soft tissue.

3. Those requiring surgical procedures eg. tracheostomy.

Care of the Tracheostomy Patient

Once tracheostomy has been performed the lungs must be protected. There are a number of procedures designed to achieve this aim:

1. Aspiration of secretions

2. Posture
3. Physiotherapy

4. Humidification of inspired gasses

5. Tracheostomy toilet

6. Strict nursing care

Physiotherapy is invaluable in that it encourages secretions to move to larger bronchi, permitting easier aspiration. Humidification of inspired air prevents the formation of crusts in the trachea.

All too often tracheostomy is mentioned in the dental literature without detailed reference to the operation itself, probably under the misguided assumption that this procedure falls outside the province of the oral surgeon. Within the general hospital environment this is usually the case, the operation being performed by a specialist 'general surgeon', or the E.N.T. surgeon. However during an acute emergency, delay while specialised attention is sought could be fatal. This emergency may occur at the site of an accident, in the dental surgery or within the hospital.

**Signs of Impairment of Airway**

Jackson and Jackson (1950) as reported by Archer (1961, p698) stressed the indrawing of the suprasternal notch as the most important diagnostic sign of obstructive laryngeal dyspnoea. The signs and symptoms of obstructive laryngeal dyspnoea which call for tracheostomy are:
1. Restlessness
2. Anxious facies
3. Ashy cyanosis
4. Rapid shallow breathing
5. Indrawing of the supra-sternal notch
6. Indrawing of the supra-clavicular fossae
7. Indrawing of the intercostal spaces
8. Indrawing of the epigastrium

In very young children indrawing of the sternum may be present.

The Tracheostomy Procedure - When the patient is unconscious no anaesthetic is required, however when the patient is conscious lignocaine locally infiltrated is an effective local anaesthetic for the elimination of operative pain.

Provided there is no mechanical or anatomical obstruction of the upper respiratory tract an endotracheal tube can be placed prior to surgery. This tube highlights the trachea and is especially valuable for young children as the trachea can be easily missed. The endotracheal tube is not removed until the tracheostomy tube is to be inserted.

The first stage of the procedure is to position the patient with the head fully extended and the chin and sternal notch in a straight line. (Fig. 1).

There are two types of incision that may be used:

- The Vertical incision
- The Horizontal incision
Fig. 1 - Tracheostomy procedure (adapted from Feldman and Ellis, 1967).
If the operation is to be without serious complication the incision must be kept to the mid-line, thus avoiding the major vessels of the neck and the possibility of missing the trachea. From the cosmetic viewpoint it is preferable to use the horizontal incision, however in an emergency and for the inexperienced the vertical incision is safer because it is easier to align and the possibility of over extension laterally does not arise. An over extended horizontal incision may conceivably sever one of the carotids or jugular veins.

The vertical incision is made in the mid-line beginning at the lower border of the thyroid cartilage to a position just above the suprasternal notch. The skin incision is deepened to the investing fascia covering the pre-tracheal muscles. This fascia is then split vertically, uncovering the pre-tracheal muscles, which are retracted, exposing the isthmus of the thyroid gland. Above the isthmus can be seen or palpated the first ring of the trachea. If it is not possible to displace the thyroid isthmus the gland is clamped and sectioned vertically. The upper rings of the trachea are now exposed. When operating under local anaesthetic it is advisable to inject a small volume into the trachea between two of the rings to prevent the violent coughing that will occur when the trachea is opened. Opening into the trachea is established between the second and third
rings by a small transverse incision. An oval shaped window is made by cutting out a portion of the trachea between the second and third rings. Alternatively the Swedish method of a tracheal flap may be used. This involves an inverted U-shaped incision in the trachea that enables the tracheal flap to be hinged forward and down. Unlike the previous method described above, this flap is repositioned after removal of the tracheostomy tube.

The largest tracheostomy tube that will comfortably fit the opening is selected.

Range of Sizes: Adults

33 to 42 French gauge

The wound is loosely closed with about three silk sutures attached to the skin and tapes holding the tube are secured behind the patient's neck.

A plastic tube with an inflatable cuff is usually employed. It offers two advantages over the metal variety:

1. Enables positive pressure ventilation.
2. Prevents pharyngeal secretions entering the tracheo-bronchial tree from above the inflated cuff.

However there is a danger that the inflatable cuff when left in situ for long periods of time may cause ulceration of the tracheal wall with possible damage to
major blood vessels in the neck.

Tracheostomy is not an easy operation and requires a degree of surgical experience; it is therefore wise for the less experienced to perform a laryngotomy (crico-thyrotoomy) when an acute emergency arises. (Fig. 2). The laryngotomy technique is as follows:

The head of the patient is held in the mid-line position with the neck fully extended. The larynx is then held between the thumb and middle finger and with the index finger in the groove between the thyroid and cricoid cartilage the cricothyroid membrane is palpated. The easiest method to locate the cricothyroid membrane is to trace the anterior border of the thyroid cartilage inferiorly until the first depression in the mid-line is encountered. With a scalpel, scissors or even a razor blade a one inch transverse incision is made over this groove. The incising instrument will pass through three layers; the skin, fascia and the avascular crico-thyroid membrane, ultimately opening into the larynx. Using a knife or scissor blades, a space is levered open. If a tube is not available, mouth to larynx respiration is performed. Alternatively, in an emergency, a ready made tube can be obtained by disassembling a ball point pen and using the plastic casing as a makeshift tube. Within twenty-four hours the patient must undergo elective tracheostomy. Delay beyond this period may result in perichondritis of the larynx
Fig. 2 - Laryngotomy: anatomy and technique (adapted from Feldman and Ellis, 1967).
and possibly stenosis.

Archer (1961, p529) prefers to puncture the cricothyroid membrane with either a trochar or a thirteen gauge needle to insufflate temporarily a supply of oxygen below the obstruction. He maintains that incision of the membrane causes post-operative scarring which may injure the larynx and the voice.

b) Chest and/or Head Injury associated with respiratory embarrassment.

The need to establish a clear airway where respiratory obstruction is present is obvious. Having obtained a clear airway inadequate respiration may still persist and this may then be due to improper lung movements. Inadequate lung movement may occur when there is:

1. Blood or air in the pleural cavity.
2. Flail chest with paradoxical respiration.
3. Severe head injury and brain stem damage.

Pneumothorax occurs when air or gas enters the pleural cavity following trauma or disease. This may occur as a result of:

1. Fractured ribs and lung puncture
2. Ruptured trachea or main bronchus
3. Open chest wound (Scott, 1971, p10)

Injury of this nature should be suspected if there is evidence of decreased breath sounds. Respiratory
efforts will increase but the patient becomes cyanotic and restless. A chest radiograph is a valuable diagnostic aid. Treatment is by insertion of an intercostal catheter to an underwater seal (closed chest drainage). (Fig. 3) On inspiration the negative intrapleural pressure sucks water up into the tube and prevents air from entering the pleural cavity. The bottle must, of course, never be raised above the chest level otherwise the fluid will be decanted into the thoracic cavity. Haemothorax is characterised by the presence of blood in the pleural cavity. This may occur from:

1. Continued haemorrhage from Parietal vessels (intercostal, internal mammary).

2. Pulmonary vessels in association with lung trauma.

3. Blood from a ruptured diaphragm and/or upper abdominal viscera sucked into the pleural cavity.

Treatment is directed towards the control of haemorrhage if continuous, and aspiration of blood from the pleural cavity.

Flail chest is a severe injury secondary to blunt trauma involving the abdomen or thorax. It is characterised by mobilisation of the chest wall so that when the patient breathes in, the chest wall sinks in and the lungs do not expand. When an isolated segment of the thoracic cage is associated with paradoxical movement then respiration
Fig. 3 - Closed chest drainage (adapted from Feldman and Ellis, 1967).
becomes inadequate and hypoxia, hypercapnoea, acidosis, decreased filling of the heart with lowered cardiac output and sputum retention with atelectasis may occur. Flail chest is best treated by endotracheal intubation and intermittent positive pressure ventilation in the first instance, followed by tracheostomy and intermittent positive pressure ventilation if intubation is unsuccessful. This immediately expands the lungs, creates adequate ventilation and often prevents the development of atelectasis and pneumonia.

**Ruptured trachea or main bronchus** is often missed and tends to occur with severe chest injuries. The patient will exhibit respiratory distress and haemoptysis. Cyanosis may also accompany the condition. Blood wells up within the bronchus causing obstruction to the passage of air.

A ruptured bronchus may present as:

1. Acute pneumothorax with persistent leak of air into the pleural cavity.
2. Chronic atelectasis and recurrent lung infections.

Diagnosis is by bronchoscopy.

**Cardiac Trauma.** Injury to the chest from blunt or penetrating trauma may not only involve the lungs and thoracic cage but also the heart. Cardiac trauma may result in haemopericardium, cardiac contusion and laceration, cardiac rupture, pericardial rupture and
injuries to the valvular mechanism.

A not uncommon feature of chest injury is cardiac tamponade, a condition attributed to the presence of blood within the pericardial sac which prevents adequate filling of the heart and so jeopardises the circulation. In essence, there is a reduced cardiac output secondary to haemopericardium following cardiac trauma. Dunphy and Lawrence (1973, p204) state "The clinical features include pallor, hypotension, distant or inaudible heart sounds, and a weak and sometimes irregular or paradoxic pulse. The neck veins are usually distended." Aspiration of the pericardium (pericardiocentesis) may be life saving and should be attempted as soon as cardiac tamponade is recognised; however if aspiration fails, immediate steps should be taken to accomplish pericardial decompression by means of open chest resuscitation in the operating room.

Trauma to main vessels. "If the patient reaches an effective hospital alive he stands a considerably better than even chance of surviving penetration of these structures" (London, 1967, p621).

There is not always much external bleeding but there are likely to be signs of either oligaemia or cardiac tamponade and if radiographs show a broad mediastinal shadow it usually means that a main vessel has bled.
A great deal of blood will be needed for resuscitation and more still if the heart and main vessels have to be explored (London, 1967, p621).

3. The Circulation

a) Control of Bleeding

Haemorrhage from the maxillo-facial region can usually be controlled by digital pressure or by the use of saline gauze with pressure and where necessary by clamping and ligation of the vessels involved. The following is a list of useful pressure points for the control of bleeding of the face and neck related to comminuted mandibular fractures.

<table>
<thead>
<tr>
<th>Source of Haemorrhage</th>
<th>Pressure Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial Artery</td>
<td>Where the artery crosses the lower border of the mandible.</td>
</tr>
<tr>
<td>Superficial Temporal Artery</td>
<td>Where the artery crosses the zygomatic process of the temporal bone just anterior to the ear.</td>
</tr>
<tr>
<td>External Carotid and Branches</td>
<td>Anterior margin of sterno-mastoid at the hyoid bone-compress against transverse process of cervical vertebrae (Atlas).</td>
</tr>
<tr>
<td>Lingual Artery</td>
<td>Deep pressure under the angle of the mandible.</td>
</tr>
</tbody>
</table>
Compression of the external carotid. Pulling the tongue forward over the teeth. Compressing the dorsum between forefinger and thumb with the tongue drawn forward. When portion of the mandible is avulsed this latter manoeuvre is more easily accomplished.

Compression as for external carotid.

Maxillary Artery

Sutures, gauze dressings under pressure, gauze packs bandaged under pressure, (haemostats, cauteroy, hot packs).

Soft Tissue

Comminuted mandibular fractures of the so called 'civilian' type are rarely associated with extensive soft tissue laceration with severe haemorrhage. However in gunshot wounds to the mandible and maxilla haemorrhage may be severe and difficult to control. These cases are liable to develop severe secondary haemorrhage. Although ligation of a major neck vessel is advocated by some, it has been found to be of limited value owing to the pronounced collateral circulation of the face.
Other means to lessen haemorrhage are:

1. Elevation of the head unless the patient is in shock.
2. Judicious use of sedatives and analgesics.
3. Use of packs.
4. Use of hot packs (49 degrees C).

Sedative and analgesic drugs are useful in the sense that they help control and limit unnecessary patient activity and reduce the level of anxiety. The nursing staff should be alert to the possibility of secondary haemorrhage. On occasions a sharp bony fragment or foreign body may remain causing a tear or erosion of a blood vessel, particularly when accompanied by local infection.

b) **Transfusion of Blood and Blood Substitutes.**

For the clinician faced with the seriously injured patient a dominant task is to restore the circulation as promptly and completely as he can and this is largely a matter of providing answers to the following questions:

1. Has there been blood loss?
2. If so, how much?
3. At what rate is depletion likely to continue and for how long?
4. Has there been any interference with the heart and pulmonary circulation?
5. Has there been any interference with the nervous control of circulation?
The most important questions are the second and third and a usefully accurate guess can be made from a study of known injuries and the general state of circulation in light of the time elapsed since the injury (London, 1967, p36).

The volume of fluid replacement depends upon accurate estimation of blood loss after trauma. Unfortunately accurate assessment of blood volume deficit is rarely possible and reliance has to be placed on simple clinical observations and measurements supported by certain bed-side and laboratory estimations (Dwyer, 1969, p30).

In emergency situations important factors in determining blood loss are:
1. The size and nature of the injury
2. The general appearance of the patient
3. The arterial blood pressure and pulse rate
4. The urinary output per hour
5. Central venous pressure (C.V.P.).
6. Occasionally measurement of blood volume by isotopic dilution.

The difficulty is in obtaining a precise knowledge of the quantity of blood lost and hence the volume of fluid and blood that must be transfused. This problem is magnified by continuing haemorrhage, the effects of narcotics and analgesics, anaesthetics and cardiac and kidney disease.
The following table is useful in the clinical assessment of blood loss following trauma.

<table>
<thead>
<tr>
<th>Injury</th>
<th>Approximate Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed fractures</td>
<td>( \frac{1}{2} - 1 )</td>
</tr>
<tr>
<td>Foot, ankle</td>
<td>( \frac{1}{2} - 1 )</td>
</tr>
<tr>
<td>Upper limb</td>
<td>( \frac{1}{2} - 1 )</td>
</tr>
<tr>
<td>Tibia</td>
<td>( \frac{1}{2} - 1\frac{1}{2} )</td>
</tr>
<tr>
<td>Femur</td>
<td>1 - 2( \frac{1}{2} )</td>
</tr>
<tr>
<td>Pelvis</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Multiple fractures</td>
<td>Add several losses</td>
</tr>
<tr>
<td>Open fractures</td>
<td>Add ( \frac{1}{2} ) to 1</td>
</tr>
<tr>
<td></td>
<td>to above</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Chest</td>
<td></td>
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Grant and Reeve as reported by Rowe and Killey 1968, p486, consider that in the initial stage the physical signs of greatest value are first and most important wound size, and secondly the level of systolic blood pressure. They maintain that blood pressure is closely related to blood volume and conclude that: "In untransfused cases with limb injuries, or abdominal injuries without peritonitis, a blood pressure of over 140mm.Hg. indicates at least an 80 percent normal blood
pressure, a pressure of 100-140 mm. indicates a blood volume of 70 per cent normal or over, and a pressure of less than 100 mm. indicates a blood volume about or below 70 per cent normal. For practical purposes a blood pressure of approximately 95 mm. Hg. may be taken to represent a reduction of blood volume to 70 per cent of the normal which is the critical level, and if blood pressure is obviously declining or remains much below this level for an hour, transfusion is clearly indicated.

After injury the patient who is pale, sweating, cold and restless with poor capillary filling of the skin and nail beds, a thin thready pulse, oliguria and hypotension has a serious blood volume deficit of at least 1,500 mls. or 30 per cent of his normal effective blood volume (Dwyer, 1968, p30). According to Lloyd (1971) "A patient in 'cold hypotension' will need blood immediately".

Further guides in the clinical assessment of blood loss come from the size and nature of the injury:

- An area of superficial injury equivalent to the patient's outstretched hand or a swelling comparable to the patient's clenched fist suggest a loss of 500 mls. of blood.
- Radiological evidence of haemothorax may indicate the presence of at least 500 mls.

Special mention is given to the fractured pelvis as this injury provides a trap for the unwary. In the first
place it can cause bleeding out of all proportion to the evident bony damage and in the second place it is disconcertingly easy to overlook this injury when there are others more obvious. Hidden bleeding from this fracture may be in the range from one to five litres of blood which is potentially fatal without immediate replacement.

Another clinical guide useful for the estimation of blood loss after trauma is the pulse rate, provided of course the presence of a rapid pulse is associated with other signs and symptoms:

- hypotension
- hypothermia
- pallor
- restlessness
- oliguria
- sweating
- poor capillary filling of fingers and nail beds.

Clark and Fisher (1956) have indicated that a pulse rate of more than 100 per minute suggests a 20 per cent deficit of the circulating blood volume. This estimation is valid provided the heart has not been damaged by trauma to the chest.

In hypovolaemia the blood vessels to the kidney constrict; the blood flow falls and so does the hourly urine output. The measurement of hourly urine output is
a reliable indication of the adequacy of blood volume. Normal levels vary with age, in the adult between 50 - 100 mls. per hour is considered within normal range. Dwyer (1969) states "Restoration of urine output to normal (60 mls. per hour) by fluid replacement offers assurance that the degree of hypovolaemia has been assessed and that the circulation to the kidneys and by inference, to the body as a whole, is now adequate even if arterial pressure remains subnormal".

However one point requires emphasis:

1. Oliguria may still exist although blood volume has been restored to a safe level. This may occur in 'renal insufficiency', in which case the kidney function is inadequate.

Thus it can be concluded, that if renal damage does not exist urine output per hour can act as a reliable guide to fluid replacement.

Another useful measurement is the central venous pressure (C.V.P.), which refers to the pressure in the superior or inferior vena cava. It can be measured by inserting a long plastic catheter through a peripheral vein and connecting it to a saline manometer. Normally C.V.P. is 6 - 12 cm. of water. The central venous pressure has probably become the most satisfactory guide to the adequacy of volume replacement, but it should be
evaluated along with blood pressure. According to Lloyd (1971) "We have adopted the following regime: the patient is transfused until either the C.V.P. reaches 13 cm. of water or the blood pressure returns to normal. If the C.V.P. pressure reaches 13 cm. and the blood pressure is still low, it is reasonable to assume that there is a myocardial deficit and in these cases we have used isoprenaline to improve the cardiac output. If the blood pressure returns to normal before the C.V.P. reaches 13 cm. of water we feel that it is safe to assume that there is a volume deficit and transfusion is continued".

Walsh and Ward (1969, p32) state "The measurement of C.V.P. provides the most valuable, readily available estimate of the adequacy of the volume of circulating blood and of progress and response to treatment in oligaemic shock. For instance a pressure of 2 - 3 cm. of water indicates considerable oligaemia, and fluid replacement is carried out until the pressure stabilises at 12 cm. of water".

The central venous pressure is a reliable indication of the capability of the heart to accept additional volume load, since congestive heart failure is the only immediate hazard to fluid replacement. According to Walker, D.G. (1969) diagnosis of congestive heart failure may be promptly established by measuring the C.V.P. which
usually will exceed 16 cm. of water. It is worth noting that C.V.P. does not reflect the vascular volume alone, but indicates the relationship between the volume which enters the heart and the effectiveness with which the heart ejects that volume. C.V.P. is determined by three factors:

1. The efficiency of the cardiac pump
2. The circulating blood volume
3. The vascular tone

In essence it is an index of circulating blood volume relative to the total cardio-vascular capacity.

Despite all the available information, the estimation of blood volume deficit remains a matter for individual assessment from the presenting signs and symptoms. The final criteria is the patient's response to fluid replacement.

When hypovolaemia exists and a clinical estimation of the degree has been made, the question arises 'What fluids' will be administered?

Certainly the adage 'the only substitution for blood is blood' is true, however under certain conditions other fluids may be administered. These fluids include:

1. Plasma (S.P.P.S.)
2. Albumin concentrate
3. Dextran
4. Ringers lactate  The Plasma Volume Expanders
5. Normal Saline
Intra-venous fluids are often introduced into veins in the back of the hand or lower arm. Occasionally it is necessary to insert multiple catheters in order to administer fluids more rapidly.

When veins are collapsed or difficult to locate an incision of the overlying skin (venous cut-down) may be necessary to enable successful venepuncture (Verne, 1969). When blood loss does not exceed 20-30 per cent of blood volume and in the absence of severe hypotension, the intra-venous infusion of a blood substitute is preferable to whole blood. The use of blood is not without danger and should be reserved for those shocked patients in which blood loss is in excess of 30 per cent of blood volume (Chaplin, 1964, p222).

Possible dangers encountered when transfusing blood (Chaplin, 1964, p223).

1. Contaminated blood
2. Haemolysis
3. Sensitivity to donor cells and plasma
4. Allergy
5. Bacterial pyogens
6. Circulatory overload
7. Unexplained febrile reaction
8. Air embolism

**Saline**

When blood is not required saline is the safest substitute.
The major disadvantages of blood substitutes are twofold:
1. There are no cells
2. There is no oxygen carrying capacity

Consequently blood volume may be restored, yet tissue hypoxia can remain. Infusion of blood substitutes alone does not prepare the patient for surgery. During the lag period whilst blood is cross-matched intravenous fluids such as normal saline may be given to maintain blood volume. However if the patient is markedly hypotensive as the result of severe blood loss, he immediately requires transfusion of uncross-matched group O rhesus negative blood.

**Stable Plasma Protein Solution** - can be used in an emergency to restore blood volume and does not require cross-matching. However, fresh frozen plasma does. There is also risk of transmitting serum homologous hepatitis which is spread more commonly through plasma which is considered a disadvantage, in that contamination of the pool is more likely. However the Red Cross Transfusion Services of Sydney destroy the hepatitis virus during preparation by heating to 60°C for ten hours (Walsh and Ward, 1969, p38). This practice is still in current use.

**Plasma volume expanders**, is a term usually reserved for synthetic materials which increase the volume of
circulating blood after haemorrhage. Strictly the term should include whole blood, serum and albumin. Dextran is the most suitable plasma expander available and is used for emergency treatment of hypovolaemic shock. However it is not as suitable as blood, albumin or stable plasma protein solution (S.P.P.S.) but it may save a life in the absence of these human materials and would be essential in times of national disaster. According to Walsh and Ward (1969, p30) "it has been shown that dextran occasionally causes a haemorrhagic state and for this reason the total amount administered should be restricted to the minimum necessary to save life".

The function of the large dextran molecules (polymer of glucose) is to increase vascular osmotic pressure and draw interstitial fluid to restore blood volume. However, fifty per cent by volume is lost from circulation in ten hours. Crystalloid solutions are included amongst the plasma expanders. Buffered saline rapidly restores water and sodium to the extracellular space, and is safe and inexpensive. To be effective buffered saline must be administered considerably in excess of estimated blood loss. Four to five times the volume of buffered saline must be infused to match each volume of blood lost. The best available solution is Ringers lactate which
contains a balanced solution of sodium, chloride and bicarbonate constituting an electrolyte concentration similar to blood.

**Albumin** is an important plasma protein serving many functions in particular the maintenance of osmotic pressure between circulating blood and tissue spaces. The effectiveness of albumin is in its ability to draw fluid from the extra-vascular spaces to increase blood volume (Verne, 1969). In dehydrated patients albumin is of little use unless additional fluids are given to supplement withdrawal from the extra-vascular spaces, thus avoiding further tissue dehydration.

It is therefore advisable to follow each 100 mls. of 25 per cent albumin administered for restoration of blood volume by 400 to 500 mls. of crystalloid solution (Walsh and Ward, 1969, p29).

c) **Diagnosis and Treatment of Shock**

The term 'Shock' is a loose term that requires clarification. It is often used by the layman to infer any physical or emotional trauma following injury. However, it should be used only to describe circulatory insufficiency. Shock is a condition which exists when there is a relative deficiency of the circulating blood volume in respect of the effective capacity of the cardiovascular tree; a relative deficiency which threatens the life of the patient. Tracy (1969, p20)
states, "in the accident victim, a mortality factor of prime importance is the state of circulatory collapse known as shock".

Verne (1969) and Blakiston (1973, p712) classify shock according to aetiology and pathophysiology into four main types:
1. Hypovolaemic or Oligaemic shock
2. Cardiogenic shock
3. Septic shock
4. Neurogenic

Hypovolaemic shock is the result of actual diminution in blood volume due to the loss of either whole blood or plasma from circulation.

Factors reducing the volume of circulating fluid are:
1. Haemorrhage (total blood loss)
2. Burns (loss of blood serum)
3. Gross dehydration (loss of extracellular fluid)

Shock from blood loss may be encountered as the result of a severely comminuted mandible, however, shock from gross dehydration, burns or infection is not a feature of facial injuries per se.

Severe blood loss is uncommon in mandibular fractures; however in gun shot wounds to the mandible or 'civilian' type injury to the face with extensive soft tissue laceration, haemorrhage may be severe and
difficult to control. Because of the infrequent occurrence of shock in conjunction with a comminuted mandibular fracture, one must suspect if the signs of shock are present, injuries elsewhere. These injuries may be internal and less easily recognised, for example crush injuries or fractured pelvis, ruptured spleen, haemothorax, fractured limbs etc. In addition hypotensive drugs, general anaesthetics and adrenal cortical insufficiency predisposes the patient to hypovolaemic shock.

The four cardinal signs and symptoms of hypovolaemic shock are:
1. Rapid pulse over 100 per minute.
2. Systolic blood pressure below 100 mm. Hg
3. Pallor or cyanosis of the face.
4. Cold hands.

These signs and symptoms usually correspond to a blood volume deficit of about 30 percent. When blood loss is less than this figure intense peripheral vasoconstriction may prevent immediate cardiovascular collapse.

The rapid correction of blood loss from circulation is not always followed by immediate recovery. This condition is referred to as 'refractory' shock and carries a high mortality. According to Walsh and Ward (1969, p38), "If severe hypotension persists for too
long, oligaemic shock cannot be treated successfully by transfusion and fluid replacement. This is called the irreversible phase of shock". Cerebral function deteriorates with loss of consciousness. In addition hypotension, tachycardia, anuria, severe metabolic acidosis and increased respiratory rate persist despite vigorous efforts to replace fluid loss.

The clinical procedures used in estimating the degree of hypovolaemia and the restoration of blood volume deficit have been covered in the previous section of this chapter.

Only brief mention will be given to the other varieties of shock.

Cardiogenic shock is the result of ineffective cardiac pumping action, which might occur in instances of myocardial insufficiency viz.,

- myocardial infarction
- cardiac arrhythmias
- cardiac arrest
- cardiac tamponade
- massive pulmonary embolism

It is important to determine if severe hypotension is the result of ineffective cardiac pumping action or the result of hypovolaemia. A comminuted fracture of the mandible may occur secondary to cardiac insufficiency in which case the primary treatment is directed toward
the cardiac pump. The signs of facial injury may be so overwhelming that shock can be falsely diagnosed as hypovolaemic, when in fact blood loss resulting from facial injury may contribute little to the existing state of shock.

**Neurogenic shock** sometimes called primary shock and better known as fainting or syncope must be distinguished from hypovolaemic shock. Fainting is a brief reaction to mental or physical stress accompanied by: pallor, sweating, weakness, dizziness, nausea, and occasional loss of consciousness due to acute cerebral hypoxia.

This transient loss of consciousness is caused by reflex peripheral vasodilatation which leads to a pooling of blood, with consequent reduction in cardiac output and cerebral blood flow (Macleod, 1974, p241). Although the arterial blood pressure is lowered the pulse rate is considerably slower than in hypovolaemic shock. Improvement is rapid when the patient lies down. If neurogenic shock is not corrected there will be a reduction of blood flow to the kidneys and brain and the patient's condition may become critical.

If the surgeon is unaware of impending syncope the patient will loose consciousness, the pupils will dilate and there will be convulsive movements of the limbs. The most effective treatment is to place the
patient in the supine position and administer oxygen. The patient should remain in this position until recovered as indicated by return to 'normal' blood pressure and respiratory rate.

4. **Head Injury**

When an oral surgeon examines a patient who has sustained a comminuted fracture of the mandible, or any maxillo-facial injury, he must be on the alert for the presence of a co-existing head injury. The very intimate anatomical relationship between the cranium and the jaws serves to emphasize the risk of such injuries occurring concurrently.

The purpose of including a resume of 'head injuries' in this thesis is to stress the need for continued awareness of the possible head injury and the need for continued observation of the injured patient for early signs of developing brain damage.

The casualty officer is often called upon to make a diagnosis of a patient in coma. It is usually easy enough to determine that unconsciousness is due to trauma, the most common cause being the motor car, followed in order of frequency by industrial, sporting and home accidents (Scott, 1971). However, it is important to remember that a drunk or an epileptic may have sustained a head injury in falling.

A person having sustained a head injury may present
with scalp laceration, a fractured skull, meningeal haemorrhage, brain damage or a combination of any of these injuries with or without significant disturbance of the general physiology of his body (Evans, 1952).

An indication of the damage received can be evaluated by examining the surrounding structures that overlie and protect the brain viz., the scalp and skull. However, severe brain damage can occur without obvious injury to these structures (contre coup phenomena).

a) Protective Structures

"The risks to life and function occasioned by a head injury are due in large measure to brain damage" (O'Connell, p634). Injury to the covering tissues are only of secondary importance.

The scalp - this is a very vascular region and bleeds freely when lacerated and occasionally bleeding is so profuse as to require a blood transfusion. Although the scalp is very vascular there is always the risk of sub-aponeurotic infection developing after injury. If this infection does arise it is usually the result of failing to observe basic surgical principles.

The skull - the skull protects the brain from injury although this protection is by no means complete. It may fracture in several ways:
1. Simple
2. Comminuted
3. Depressed
4. Compound
5. Complicated

The thickness of the skull varies according to location, however, the base is the weakest area because of the presence of several anatomical 'weak areas'. These are:

1. Frontal sinuses
2. Ethmoid sinuses
3. Otic air sinuses
4. Cribriform plate
5. Orbital fissure
6. Foramina of the middle and posterior cranial fossae

**The dura** - A fracture of the cranial base will as a rule result in discharge of cerebrospinal fluid via the ear, nose or into the nasopharynx. On odd occasions the cerebrospinal fluid will leak into the orbit via the lateral ethmoidal air cells, producing a fluctuant swelling above and medial to the globe (Leopard, 1971).

C.S.F. leak via the nose (rhinorrhoea) is the most common discharge and is diagnostic of a fracture involving the anterior cranial fossa. The degree of injury may only be a simple fracture of the cribriform plate.
Dural injury is most likely to occur in high level fractures of the middle third of the facial skeleton, in particular the naso-ethmoidal fractures.

On rare occasions (1.4%) head injury is accompanied by C.S.F. leak via the ear (otorrhoea). Twenty percent of such cases develop meningitis (Caniff, 1971). Otorrhoea is indicative of a fracture involving the middle cranial fossa which may occur following a blow to the temple; superior displacement of the condyle and occipito-mastoid trauma.

Dural repair is positively indicated in the presence of persistent or recurrent C.S.F. leak; escape of brain substance; recurrent meningitis and aerocele. However, in the majority of cases natural healing of the dural tear occurs after fracture reduction thereby preventing meningitis, aerocele and persistent C.S.F. discharge.

b) Intracranial Injury

The Brain - The extent of brain damage will depend upon the direction, frequency and severity of the forces applied to the head. Excluding the effect of intracranial haemorrhage brain damage can be divided into three groups:

1. Concussion
2. Contusion and laceration
3. Mass shift of brain substance
Concussion - this can be considered a diffuse generalised brain injury and defined as a transient loss of consciousness following blunt trauma to the head without obvious pathological injury to the brain substance. This view is not strictly correct and concussion is now considered in some cases to cause permanent pathologic change. Certainly severe concussion is characterised by slow recovery which may take months or even a year or more. For some patients complete recovery never returns. Hooper (1969, p32) states "the patient may still remain in a state of grossly impaired consciousness typical of lesions in the upper midbrain area involving the reticular formation". He suggests that much of the acute phenomena of concussion are related to changes in the brain stem and in particular the reticular formation which is so essential for maintenance of the conscious responsive state.

The transient loss of consciousness so characteristic of concussion is followed by a period during which the patient is dazed exhibiting automatic behaviour for which there is no recollection (post-traumatic amnesia).

Another feature of concussion is the loss of memory for the events immediately preceding the impact (retrograde amnesia). The extent of the amnesic phase
particularly the post-traumatic amnesia is a function of the degree of brain injury.

Contusion and Laceration - contusion and laceration of brain substance directly beneath the blow is a more severe injury than that of concussion. Tearing of the dura mater, damage to brain substance and haemorrhage may occur with both types of injury.

Classically contusion is produced by a simple denting of the skull followed by rebound to normal contour. Lacerations are more likely to occur following a penetrating wound, a depressed fracture or after a comminuted fracture of the skull. The degree of neural damage will be reflected by the extent of motor and sensory impairment. (Fig. 4)

Mass movement of brain substance - According to Scott (1971, p2) such an occurrence may lead to the following changes:

a) Tearing of white matter within the hemispheres
b) Contré coup injury
c) Neuronal damage with functional inactivity
d) Cerebral oedema

Acceleration or deceleration that is suddenly and violently applied will produce these injuries without apparent injury to the scalp and skull. The clinical picture will vary according to the severity of the injury.
Fig. 4 - Depressed fracture of the skull (adapted from Ring, 1964).
Haemorrhage - Intracranial haemorrhage is a serious sequela of some head injuries. It is capable of producing compression and displacement of brain substance immediately below the haematoma. Severe compression and displacement is frequently fatal.

There are three planes into which haemorrhage can occur:

1. Extradural
2. Subdural
3. Subarachnoid

The presence of a developing intracranial haematoma can effect the brain in two ways:

1. Local pressure on the brain underlying the haematoma resulting in disturbed circulation, cerebral oedema and midbrain compression.

2. Herniation of a portion of the temporal lobe through the hiatus of the tentorium resulting in distortion and disturbed circulation of the brain stem. (Fig 5)

The clinical signs of developing intracranial pressure secondary to haemorrhage are covered under the following section.

c) Clinical Signs of Developing Intracranial Pressure

Following cranial trauma a patient may present with headache and drowsiness as the early symptoms of developing intracranial pressure. As the patient's
Fig. 5 - The progressive downward displacement of the cerebral hemispheres causing vascular changes in the upper and lower portions of the brain stem. (Adapted from Hooper, 1969).
condition deteriorates the following signs become obvious:

Level of Consciousness - The state or level of consciousness must be recorded in simple terms that relay meaning such as "The patient is conscious but confused"; "the patient is alert, cooperative and orientated"; "the patient realises he is in hospital and is injured"; or "the patient is unconscious and unresponsive to verbal commands". The degree of responsiveness to graduated stimuli is an appropriate clinical measure of the level of consciousness.

According to Ring (1964, p30) "Those who are deeply unconscious will not respond to any stimulus, however painful, and spontaneous movements may only be respiratory. At a lighter level reaction to painful stimuli may be present and purposive movements may occur. As time passes the victim may respond to his name and perform simple movements on request. Levels of consciousness cannot be easily classified, and it is better to record what the patient does and how he reacts, than to try to define accurately the level of coma".

Any shift from a higher level of consciousness to a lower level is a sign of deepening coma. As coma deepens there are to be seen pupillary changes indicative of brain injury.
Fig. 6 - Initial pressure stimulation on the oculomotor nerve by the cerebral hemisphere (adapted from Potter, 1968).
... oculomotor palsy - initially there is a transient constriction of the pupil on the affected side due to initial stimulation of the occulomotor nerve as it is stretched by the herniating temporal lobe. (Fig. 6)

The clinical sign is soon followed by dilatation of the pupil due to paralysis of the displaced nerve. As compression continues to develop, cerebral circulation becomes increasingly impaired and generalised oedema of both hemispheres occurs. At this stage both pupils will be widely dilated. The presence of bilateral widely dilated and fixed pupils is an ominous sign that carries a ninety-five percent fatality (Thoma, 1963, p367). Ellis and Calne, (1972, p87) state that the presence of bilateral dilated and fixed pupils indicate very great cerebral compression from which the patient rarely recovers. Bleasel (1969, p45) maintains that it is usual for pupils to dilate widely following painful stimulus. Abnormal pupils on the other hand are enlarged and unresponsive when the neck is pinched. It is also normal for the eye balls to rove and the pupils to fluctuate in the unconscious patient without brain damage.

The presence of an ipsilateral dilated pupil is one of the classic signs of an extradural haematoma, however, consideration must be given to the possibility of direct optic nerve damage. It is therefore important
to determine whether this disparity is the result of disturbed brain stem conduction or the result of direct trauma to optic nerve. (Fig. 7)

The following test is useful in determining the structural integrity of the optic nerve. In the absence of optic nerve damage light shone into the affected eye (dilated fixed pupil) will cause the pupil in the other eye to constrict reflexly. This is known as the consensual light reflex. However, if the optic nerve is damaged the consensual light reflex is not present, although the direct light reflex in the unaffected eye is present, but as cerebral compression continues to develop and becomes more widespread, both pupils will become dilated, and unresponsive (bilateral oculomotor paralysis).

Hemiparesis or lateralised weakness is a sequela of increased intracranial pressure which causes herniation of the uncus of the temporal lobe through the hiatus of the tentorium. Herniation pressure disturbs circulation to and distorts the upper portion of the brain stem (cerebral peduncle). This compression and distortion results in lateralised weakness on the same side as the haematoma. Continued pressure produces a bilateral hemiparesis and changes attributed to disturbances of the central portion of the brain stem (pons) viz., elevated blood pressure, bradycardia, and irregular respiration.
Fig. 7 - The anatomical pathway for the oculomotor and optic nerves. Note at A conduction is disturbed and the pupil on that side is dilated and fixed.
. **Blood Pressure, Bradycardia and Irregular Respiration**

To reiterate the presence of continued circulatory and pressure disturbance has its effect on the pons. By far the most important clinical sign is the alteration in respiratory rhythm. Extremes of rhythm particularly just after an accident are indicative of severe brain damage. Normal sleep according to Bleasel (1969, p47) is accompanied by respiration that is mainly inspiratory effort followed by elastic contraction for expiration. However, in the presence of cerebral compression affecting the brain stem, respiratory effort becomes strongly expiratory and forcible expulsion of air after inspiration gives the unnatural automatic 'to and fro' sound of stertorous breathing.

. **Temperature control** and brain stem damage can cause difficulties in management of high temperature. High temperature will lead to a deterioration in the state of consciousness and must be reduced to normal levels, if necessary by using ice packs.

. **Decerebrate rigidity** is always accompanied by gross depression of the level of consciousness, oculomotor disturbance and respiratory and vasomotor changes. The neck is stiff, the back arched and all four limbs are maintained in extension except for the wrists which are flexed. According to (Potter, 1974, p14) decerebrate rigidity of extensor muscles is commonly
present in varying degrees following a severe brain injury. The spasm may be intermittent or may be precipitated in response to a stimulus.

- **Dysphasia** - or loss of the faculty of speech is a useful sign of cerebral clot over the left cerebral hemisphere. Potter (1974, p14) states "A sensitive test is to confront the patient with a series of ten or so common objects and to ask him to name them. If dysphasic he will be unable to do this, to an extent that is clearly abnormal".

- **Conclusion** - The presence of a head injury must always be kept in mind by the oral surgeon examining the comminuted mandibular fracture patient. Head injury can be overlooked particularly if the fractured mandible is the only obvious injury.

5. **Prevention and Control of Infection**

a) **Infection and Facial Injury**

Oro-facial infection is an unwanted sequela of facial injury. It is a sequela that must be guarded against by meticulous debridement, antibacterial therapy and primary surgery. The comminuted mandibular fracture offers opportunity for infection as this fracture is frequently compound and therefore open to oral flora and external micro-organisms contaminating the skin. The extreme example of such an injury is the gun shot type comminution with avulsion of bone and overlying soft tissue.
Morgan and Szmyd (1968) in a paper on maxillo-facial war injuries state, "control of infection was a difficult problem in patients with wounds caused by high velocity missiles". They also state, "infection, hard and soft tissue loss, and immobilisation of the injured bony elements were management problems". Civilian injury as a rule is less severe, infection is a lesser problem and management more straightforward. With the frequent cause of such civilian injuries being automobile accidents and assault, it is found that disruption of soft tissue covering the mandible on its intra-oral and extra-oral aspects is usually less extensive. This is not to say however that on occasion with these types of civilian injuries gross loss of oro-facial tissue does not occur. The American College of Surgeons Committee on Trauma 1965, p51, made the following rather obvious statement that "All open wounds resulting from accident or violence should be considered contaminated by bacteria". The recognition and acceptance of this fact guides our general approach to the prevention and control of infection in facial trauma. This contamination may of course be varied in degree.

According to Zaydon and Brown (1964, p23) "Treatment should be directed with this in mind so that conditions consistent with bacterial growth and hence
the development of a clinical infection, can be either avoided or corrected". Contaminating agents may be clothing, glass, soil, dust, teeth, denture fragments, wooden splinters, water, oil, chemicals or whatever medium surrounds the wound at the time of injury.

According to London (1967, p57) "our present degree of control over infection owes an incalculable debt to antibacterial substances in general but the success of antibiotics, in particular, in preventing and treating sepsis in wounds has depended very largely on their being used as adjuvants to surgery".

All too often antibacterial drugs are employed with little forethought or discrimination but it is only with a rational approach to their use that their true effectiveness will be seen. Kay (1972, p56) states "Ideally antibacterial agents should be used as precision instruments and, whenever possible, only prescribed after the infecting organism(s) has been identified and its sensitivity to various antimicrobials assessed in vitro". However, in the majority of circumstances a patient with a comminuted mandible is given penicillin for, or as a prophylaxis against infection. The patient's condition does not justify delay in antibiotic treatment until sensitivity tests are carried out. Since penicillin is usually most effective against micro-
organisms incriminated in oro-facial infections, it is the drug of first choice. This is not to say that sensitivity tests should not be instituted. In the event that such tests show penicillin to be ineffective against the organism or organisms involved, an effective antibiotic is substituted.

Antibacterial agents should be used in conjunction with surgery and not as a substitute for it. Mechanical measures such as debridement, immobilisation and surgical drainage in suitable cases of established infection will aid in the prevention and limitation of infection.

b) Aetiology of Infection

Many factors enter into the aetiology of infection. The American College of Surgeons Committee on Trauma (1965, p51), enumerates several factors that influence the degree of contamination and favour the development of infection. The following is a list of such factors:

1. Nature of the wounding agent.
2. Velocity of the agent producing the wound.
3. Amount of tissue damage and impairment of local circulation.
4. Surface area and depth of the wound.
5. Prior treatment, if any.
7. Relative vascularity of the tissue involved.
8. Proximity of the wound to the natural and endogenous sources of contamination.
9. Co-existence of disease which may reduce tissue resistance to infection.
12. Exposure of the patient to radiation.
13. Steroid therapy.

c) The Essentials in Prevention and Control of Infection

Wound care is designed to produce conditions favouring rapid, uneventful healing with minimal opportunity for proliferation and invasion of microorganisms. The following four procedures are important:
1. Cleansing and debridement
2. Immobilisation
4. Primary closure of wounds.

These procedures are all elaborated in the chapter on facial wounds except the administration of antibacterial agents and anti-toxins.

The selection of an antibiotic prior to a bacteriologist's report is largely a matter of clinical acumen based on past experience in caring for similar facial injuries. Penicillin is the drug of choice. This treatment is not just a matter of custom but a well founded therapeutic measure. The work of Burh and Scott
(1959) suggests that Staphylococcus aureus is the chief contaminant of most wounds. Despite the existence of predominately resistant strains in the hospital environment, there is a good chance that staphylococci entering the wound outside the hospital will be sensitive to penicillin. The resistance to benzylpenicillin by staphylococci has been reported as fifteen percent in the general population and ninety percent within the general hospital (Kay, 1972, p66).

Longstanding wounds and wounds contaminated by road dirt and soil usually contain Gram negative organisms and should be protected by a tetracycline or chloramphenicol or ampicillin (London, 1967, p60).

In the event that there is resistance, it is unwise to discontinue the original antibiotic immediately as it may be supressing micro-organisms in the wound flora that are not sensitive to the second antibiotic. With the immediate release of these organisms from the control of the original drug, proliferation and development of resistance may occur.

d) **Indications for Administration of Antimicrobial Drugs**

The concept of 'routine' prophylaxis accepts as a justifiable risk the possibility of hypersensitivities and fatal anaphylaxis. London (1967, p 61) states "It is tempting to argue that antibiotics should be
given 'to be on the safe side', but this ignores the
dangers of allergy and of promoting the development of
resistant organisms in the patient and his environment'.
However there is no doubt that under the following
circumstances antibiotics should be given:
1. Any compound comminuted fracture
2. Delayed treatment
3. Meddlesome management before arrival at hospital
4. Presence of debilitating disease
5. Existing sepsis
6. Implantation of foreign bodies especially organic
matter
7. Valvular-septal defect

Because of the profound vascularisation of the
facial area it is quite resistant to infection and
antibiotics need not be given in simple clean
lacerations of the skin. When a soft tissue wound is
extensive antimicrobial agents are most certainly
indicated. Gunshot comminution with soft tissue
disorganization is a classic example. In fact any
commminuted mandible with overlying soft tissue damage
allowing communication between the fracture and the
oral cavity or skin surface represents a definite
indication for immediate antibiotic therapy.
e) **Prevention of Tetanus**

As a routine prophylactic measure anti-tetanus serum is frequently administered where soft tissue injuries exist and when there is risk of contamination with road dirt.

Although cervico-facial tetanus is very rare owing to the excellent blood supply of the head and neck soft tissues it is a wise precaution to give an injection of 1,500 International Units of anti-tetanus serum (passive immunization).

However, there is some debate as to the justification of administering anti-tetanus serum in view of the possibility of anaphylactic shock due to serum sensitivity.

There is a trend to rely more and more upon careful tissue cleansing and debridement in association with an antimicrobial agent such as tetracycline or penicillin. Rowe and Killey (1968, p704) states "The rational choice is between the separate administration of an antibiotic or tetanus antitoxin (anti-tetanic serum) and a well judged compromise is sometimes a combination of the two".

Ideally the general population should be actively immunized as a prophylaxis against tetanus, especially those at risk by way of occupation.

French (1974, p78) states "Contaminated injuries must be treated by the removal of all debris and non-viable tissue. The immediate danger of tetanus can be
reduced by the injection of a large dose of a long acting preparation of penicillin followed by a ten day course of oral penicillin. If wound sepsis is present cloxacillin should be given as penicillin may be inactivated by penicillinase produced by staphylococci." When the risk of tetanus is judged to be present tetanus antitoxin should be given and later the patient actively immunised with toxoid. Toxoid should be repeated one month and six months after the initial dose.
Immediate Care of The Acutely Injured — References


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The Management of Soft Tissue Injuries

Comminuted mandibular fractures are often if not always associated with soft tissue injuries and their management is an integral part of overall treatment.

1. General Considerations

"Thorough wound cleansing, gentle tissue handling and meticulous repair generally assure excellent healing of facial injury" (Zaydon and Brown, 1964, p32). Careful evaluation of the local anatomy is essential before surgical repair is begun. The aim of treatment is to repair tissue so that an acceptable aesthetic and functional result is achieved. Patients are intensely concerned about their facial appearance. Disfigurement may create a psychological and social cripple. It is of utmost importance to preserve facial tissue at the stage of primary repair as secondary repair by grafting never assumes the original character of the face.

Harold D. Gillies (1957, p10), relates his experiences during the Great War, his statement reflects the opinion of that time:

"Appearance was of secondary interest, and like a duelling scar, an ugly war wound in the enemy camp was a mark of honour".

Times have changed and certainly where civilian injuries are concerned the acceptance of residual scarring
and deformity is less acceptable than First World War wounds.

2. Classification of Soft Tissue Injuries

The classification of Osbon (1969) will be adopted.

- Abrasions
- Contusions
- Lacerations
- Puncture wounds
- Burns
- War wounds

**Abrasions** are usually superficial and result from scraping or rubbing off of surface skin to a variable depth, thereby leaving a raw bleeding surface. Pain is a frequent feature of this type of injury.

**Contusions** are the result of blunt trauma producing a bruise without a break in the skin. Subcutaneous bleeding is usually self limiting and contamination or infection are rarely encountered. A contused area is typified by its early bluish discolouration and followed by the well known changes in hue as resolution progresses.

**Lacerations** are produced by sharp objects that create a clean cut wound with sharp margins. The most usual laceration is the linear tear. Lacerations may be superficial skin incisions or deep extensive wounds involving the underlying musculature, glands, nerves
and vessels. They represent the most common facial wound.

Puncture wounds are produced by sharp objects such as a sharp instrument piercing the skin eg. stake, knife, sharp metal objects in or on motor cars or by small fragments of an exploding grenade.

Burns are classified as first, second and third degree (Osbon, 1969). Ellis and Calne (1972, p101 classify burns as:

a) Partial thickness - germinal layer intact
b) Full thickness - germinal layer destroyed

First and second degree burns are partial thickness burns and are separated on clinical grounds which reflect the degree of epithelial destruction. First degree burns produce erythema of the skin and are quite superficial. The erythema is the result of capillary dilatation in response to heat irritation. When blistering or vesiculation of the skin occurs the burns are classified as second degree. This reflects more severe tissue damage and the blisters are formed secondary to exudation of plasma beneath coagulated epidermis. In both second and first-degree burns the germinal layer is intact and healing proceeds without scarring.

Full thickness or third degree burns represent severe damage to the epidermis, the germinal layer being
destroyed and accompanied by varying degrees of damage to the underlying connective tissue. Healing is by dense fibrous scar formation, unless the wound is grafted.

On burns Wallace and Sutherland (1967, p532) state, "Not only is there local destruction but there are also widespread systemic effects".

Ellis and Calne (1972, p10) summarise the general effects of burns as follows:

1. Pain - superficial burns pain more than deep burns as nerve endings are stimulated rather than destroyed.

2. Plasma loss - there is intense exudation of plasma due to increased permeability of capillaries and arterioles. Plasma loss is most during the first twenty-four hours and ceases at about forty-eight hours after a coagulum forms.

3. Oligaemic shock - shock is a direct result of plasma loss and is proportional to the surface area of skin destroyed.

4. Anaemia - the result of cellular destruction within damaged capillaries and small arterioles and from a direct toxic effect which is inhibitory to bone marrow if the burn becomes infected.

5. Stress reaction - adrenocortical response resulting in sodium and water retention, potassium loss and protein catabolism. This response occurs in any
severe injury and should be expected to occur following comminution of the mandible particularly if large areas of soft tissue are disorganised.

6. Toxaemia - this is a combination of factors which includes biochemical disturbance, plasma loss and infection.

It is not the scope of this thesis to cover the treatment of burns, but merely to state the principles of treatment viz. - relieve the pain, control infection, treat oligaemic shock and if appropriate graft skin.

War wounds - are classically the result of a high velocity missile producing an avulsive, penetrating, perforating or impregnating wound.

An avulsive wound is characterised by the loss and disorganisation of tissue. Bullet wounds are typically avulsive. When a bullet creates a facial wound there is usually fragmentation of teeth and bone which in effect act as secondary missiles creating more extensive tissue damage. The entrance wound is frequently small, however the exit wound is explosive (Osbon, 1969, Clarkson & Walker, 1968, p468). Gunshot wounds are typically comminuted with gross destruction of the underlying skeletal framework often associated with much soft tissue disorganisation.
Clarkson and Walker (1968, p468) state "In the case of a bullet, the entry wound is usually small and comparatively clean, whereas fragmentation missiles usually inflict a ragged contused gash, or in case of large fragments avulse large segments of tissue such as an entire mandible from angle to angle". An impregnating wound is a blast type wound in which dirt particles of all sizes are impregnated a centimetre or two within the tissue. Tattooing is almost inevitable. Gross contamination is a feature of blast injuries as dirt particles, clothing and plastic or metal fragments are carried deep into the tissue (Osbon, 1969).

3. **Timing The Repair**

Immediate repair has three advantages:

a) Reduces oedema

b) Reduces contamination and infection

c) Reduces the incidence of unnecessary scar formation

Postponement of soft tissue repair until oedema subsides is an unnecessary delay which only compounds the severity of the problem and adds to the complexity of repair (Zaydon & Brown, 1964, p32). However, a laceration associated with an underlying fracture is not generally repaired until the fracture is reduced and fixed. This avoids the disruption and distortion of a meticulous soft tissue repair that inevitably occurs during manipulation of the fracture. Immediate repair
is not an absolute essential but should be undertaken as soon as practicable.

Osbon (1969) collected data on 1600 patients sustaining combat injuries encountered in Vietnam and used this information as a basis for a paper on "Early treatment of soft tissue injuries of the face". He concludes "The immediate definitive treatment of maxillofacial wounds favourably influences the outcome of all degrees of facial injury". He further states, "When closure was accomplished within the first twenty-four hours, there was a decided improvement from the aesthetic viewpoint and the patient's psychological condition certainly was improved". Early repair permits an earlier return to function.

Holdsworth (1968, p659) states "Prior to the era of antibiotics it was axiomatic that any wound which had been open for twenty-four hours was infected, but this is no longer the case, and closure can be safely carried out if infection has been present by the effective administration of penicillin". The use of Penrose type drains during closure of infected wounds is nevertheless a sound procedure.

Placing a fixed time limit during which primary repair is undertaken is an artificial approach. Times are only indications or guides as to the period a wound is open to contamination. Obviously the decision to close
a wound primarily is based on the presence or absence of infection, the nature of the wound, the degree of secondary healing present and the presence of viable tissue capable of being apposed. Thus the decision for primary closure depends upon the accurate assessment of each wound. However, it is worth remembering that in health the tissues of the body are sterile, but when open the degree of contamination will be greater the longer the wound is exposed.

4. **Principles of Treatment**

The face is a profusely vascular region that favours healing. Knowing this the surgeon is conservative in his approach to soft tissue care.

Principles of treatment can be *arbitrarily* divided into three phases:

a) **Wound Preparation** - meticulous wound cleansing
   - haemostasis

b) **Debridement**

c) **Closure** - primary and secondary
   - specific injuries
   - principles of closure

a) **Wound Preparation**

Meticulous wound cleansing and haemostasis is essential before accurately evaluating tissue damage. Visualisation of anatomical landmarks is made considerably easier after the wound is cleaned and bleeding controlled.
During the cleansing phase of wound preparation additional tissue damage by rough careless handling must be avoided. Furthermore, irritating cleansing solutions are very rarely used if avoidable. Initially to prevent further contamination the wound is covered with a dry gauze dressing (in ward) or a moist dressing (at time of surgery). The wet dressing is one soaked in 1:1000 aqueous Zepharin solution or Cetavlon. This dressing may be packed into the wound and serves two purposes:

1. Prevents contamination from adjacent skin.
2. Protects the open wound from irritating cleansing solutions.

The cleansing solutions are usually minor irritants to intact skin, but severe irritants to an open wound. Preferably the surrounding skin should be cleansed with a bland white soap or surgical soap (Phisoheal or Septisol) using gauze or a soft brush. With female patients all cosmetics are removed, and male patients are shaved in selected areas. Shaving the hair-line is contraindicated when it acts as an essential landmark for accurate wound closure. Shaving the eye brow should be avoided for two reasons:

1. It is a useful landmark in wound closure.
2. A shaved eye brow may take six months to grow and furthermore the brow may remain permanently sparse and irregular.
Any blood clot, teeth fragments and foreign bodies are removed during the cleansing phase. At times it may be necessary to use organic solvents such as benzene or ether soap for those wounds contaminated by road dirt, tar or oil. For the removal of embedded foreign matter, a stiff brush, scalpel or curette are useful. Blast injuries will produce tattooing unless the dirt particles are carefully removed. The small curette is useful for this purpose. In order to avoid pain, preparation of large wounds should be carried out under general or local anaesthesia. A general anaesthetic is preferable when the wounds are extensive or infected; when the patient is uncooperative; when the wound cleansing is likely to be lengthy and bleeding is difficult to control.

Zaydon and Brown (1964, p33) avoid the use of soap and strong antiseptics in open wounds. Osbon (1969) however reports favourably on the use of surgical soap in open wounds and surrounding tissue, followed by copious irrigation with normal saline. Holdsworth (1968, p658) prefers to cleanse open skin wounds with normal saline but recommends the use of soapy water for mucosal surfaces.

Although mild soaps appear to be useful in cleansing wounds, it must be avoided about the eyes. Normal saline is preferred because it is the most
innocuous solution. Ashbell and others (1967) advocate the intermittent use of neo-sporin ointment between sponging. Hydrogen peroxide 3% strength is helpful for the removal of residual blood clot.

"Although all of the steps of wound closure were important, cleansing was probably the most critical" (Osbon, 1969). This is understandable as a foreign body will promote infection, delay healing and may cause unsightly pigmentation. Certainly contamination of a wound in the presence of blood clot is an open invitation to infection.

**Haemostasis** is essential to good wound healing. The presence of a haematoma within a closed wound is an excellent culture medium for bacterial growth. Bleeding frequently resumes during the cleansing and debridement.

Closure should not be undertaken unless bleeding is controlled and this must be done with meticulous care. The use of vacuum drains and pressure dressings will reduce the incidence of haematoma and this has been a great advance in all forms of surgery.

**Control of bleeding** may be achieved by the following methods:

1. Clamping
2. Ligation
3. Pressure
4. Electrocoagulation

5. Hot Packs (49°C)

6. Cold Packs

Haemostats or artery forceps of many types are available for general use around the jaws. Mosquito forceps are excellent for grasping the bleeding vessel without clamping large amounts of adjacent tissue. Clamping large masses of tissue will compromise vitality and possibly important structures such as the Facial nerve. Digital pressure may be applied to compress larger vessels against a firm base of bone or muscle until the source can be located and accurately clamped. For this purpose larger haemostats are used. Moderate to large vessels can be readily ligated, however, the minute vessels may require electrocoagulation, pressure or clamping to control bleeding. In the casualty department it may be necessary to control bleeding temporarily with clamps left in situ until the patient is transferred to the operating theatre for careful clamping, ligation or arterial repair.

In some circumstances Cushing Clips can be used to control bleeding. These are small, malleable, metallic clips placed around an inaccessible vessel and squeezed tight using a special clip handling instrument.
b) Debridement

Following wound cleansing and the arrest of bleeding it is possible to accurately ascertain the extent of the wound and the next step is to remove all tissues that will not survive.

Holdsworth (1968, p658) uses the term debridement to be synonymous with the "Removal of all devitalised tissue". The removal of foreign material such as road dirt, tar, splinters or glass etc. is referred to as wound cleansing or wound toilet. In this thesis debridement is taken to mean the removal of devitalised tissue.

"Conservatism is the key note in debridement, because there is only minimal expendable facial tissue" (Zaydon & Brown, 1964, p34). When in doubt it is probably better to leave tissue that is of borderline viability as it may survive. Terry (1969) states "Fortunately, the generous blood supply to the maxillofacial region and associated healing potential and relative resistance to infection make it possible to exercise extreme conservatism in surgical debridement". However, failure to remove frayed and damaged edges of a laceration will result in the formation of an ugly scar, no matter how perfect the technique of closure. "When a shred of tissue is hanging loose, it can be retained to assist closure if the edges are bleeding,
otherwise trimming is necessary until a satisfactory edge is encountered" (Holdsworth, 1968, p659).
Extensively contused or irregular skin edges of a laceration may be debrided very conservatively to provide a clean margin so that a curved or straight line repair can be attained. A linear skin incision will heal more rapidly and with less scarring than the most meticulous repair of an irregular wound.

Radical debridement may convert a relatively simple repair into one requiring extensive secondary reconstructive surgery. Only minimal amounts of tissue should be removed. Radical debridement on the grounds of possible gas gangrene is unjustified as this is an exceptionally rare complication of facial injury. The excellent blood supply of the face allows the surgeon greater leeway for retention of soft tissue of borderline viability (Terry, 1969).

When excising the irregular margin of a wound, it is preferable to undermine the skin with a sharp scalpel and then trim the margins with the same instrument or a small pair of sharp scissors. Skin hooks may be used to advantage as they avoid further damage to the free margins of the wound that may occur from overhandling and heavy instrumentation. Holdsworth (1968, p665) uses skin hooks in place of MacIndoe tissue forceps, he uses them to evert the tissue edge during
the passage of the needle. Fischl (1965) reports that some surgeons even resort to using fingers to avoid damage to the skin edge.

Debridement of bone fragments should be conservative. Only bone that is completely free of periosteal attachment and those pieces which are washed free by vigorous irrigation are removed. However if there are numerous detached pieces of bone, which if removed would create a major residual defect on healing, then one should consider their use as a 'chip' bone graft. However, with respect to the conservation of comminuted bone there are certain issues to consider:
1. The presence of infection
2. The delay in antibiotic cover
3. The presence of a communication with the oral flora

If infection is established or likely to be established, particularly in grossly contaminated wounds, the risk of the bone chips sequestrating is ever present. Ideally they should remain in a state of 'aseptic necrosis' not septic necrosis.

c) **Closure**

To reiterate, early closure is desirable for the following reasons:
1. Early return to function
2. Minimise infection
3. Minimise scar formation
4. Promotes healing
5. Psychologically desirable to the patient

There are two basic methods of closure:

1. Primary
2. Secondary

**Primary closure** of a wound can only be achieved when there is sufficient soft tissue available to be apposed. It is often necessary to undermine beneath the subcutaneous tissue in order to achieve adequate relaxation for primary closure. If there is a full-thickness laceration of the cheek or lip the wound is closed in layers, viz. the mucosa, intermediate tissues and skin in that order.

The oral mucosa is delicate but elastic and unless there has been considerable loss of tissue, closure is usually possible aided occasionally by gentle undermining. 3/0 or 4/0 silk on an atraumatic needle is commonly employed for suturing oral mucosa. 4/0 nylon is well tolerated and can remain in situ for lengthy periods of time without causing tissue reaction.

The intermediate layer of the cheek is best closed using 3/0 catgut to approximate the muscle layer and obliterate dead space. The lip can be suitably closed using 4/0 catgut. If correctly placed the intermediate sutures should bring the skin edges together so that skin sutures may be placed free of tension. Tight
suturing taking a large bite of muscle and fat may
devitalise part of the intermediate layer.

According to Holdsworth (1968, p662) "The correct
role of skin sutures is to adjust the apposition of the
edges rather than draw them together". Tight sutures
devitalise the area encircled, promoting wound sepsis
and, cutting into the skin, may leave permanent marks.

Zaydon and Brown (1964, p42) observe that a forced
repair (drawn together under tension) causes added tissue
necrosis, scarring and distortion.

There are three essential principles of skin closure
(Holdsworth, 1968, p662)

1. Use of fine material (6/0 silk or nylon)
2. Use of fine needles (No. 3 curved atraumatic needle)
3. Recognition and removal of poor sutures (ie. badly
placed, poor eversion).

The author suggests the following thread thickness
for use in suturing:

Scalp 4/0
Lips 5/0
Face 5/0 or 6/0
Eyelids 6/0

Thick suture material, stout needles and poor
suturing technique needlessly scar tissue.
The ideal skin suture should evert the margin of the wound. Inverted or flat margins heal as a retracted scar. To achieve eversion the sutures must be placed so that the tissue held is broader at the base.

The use of skin hooks assists in gentle handling of tissue when inserting the sutures. Toothed tissue forceps (MacIndoe pattern) are useful in handling subcutaneous tissue, however, they may traumatise the skin edge in the hands of all but the most experienced.

"Surface sutures generally are placed about 1 mm from the edge and applied close together (1 to 2 mm apart) for very accurate skin approximation" (Zaydon & Brown, 1964, p40). Holdsworth (1968, p664) on the other hand suggests the sutures be placed 2 mm from the skin margins and 8 mm apart. He claims that if the sutures are placed too near the edge of the wound and too close together, they fail to bring the mesodermal or subcutaneous tissue into apposition. Haematoma formation ensues, which almost invariably becomes infected leading to breakdown of the suture line.

Judging from the excellent results obtained by Zaydon and Brown, as illustrated in their text on facial injuries, it seems immaterial if sutures are placed 1 or 2 mm from the skin edge or spaced 2 mm or 8 mm apart. What is important is meticulous subdermal
closure. An unsightly feature of poor technique is the 'step ladder' scar that results from sutures being placed too far from the skin edge and too far apart. Other causes of the 'step ladder' scar are:

1. Pressure necrosis (tension sutures)
2. Prolonged sutures (late removal)
3. Large needles and stout silk

Additional scarring occurs if haematogenous crusts are allowed to remain about the sutures or if infection develops in the wound.

Conventional methods of wound closure by means of absorbable and non-absorbable sutures don't always produce acceptable results. Even with gentle and accurate techniques of wound closure, there are times when the residual scar is cosmetically unacceptable. The shortcomings of suture material are well known, such as minor inflammatory reactions about sutures, skin marks, either temporary or permanent. The ultimate aim of wound closure is to produce an 'invisible scar'. Gibson and Poate (1964), recommend the use of adhesive surgical tape in plastic surgery. They summarise by saying "The strips appear to be of more universal use in conjunction with conventional suture materials than by their use alone. It is suggested that their use represents an important step forward in the search for the technique that will produce the 'invisible scar'".
A subcuticular suture of fine nylon may be employed for approximating skin edges. This has the advantage of eliminating the possibility of residual scarring from sutures but in the hands of the inexperienced irregular margins and puckering will occur.

**Secondary closure** - when wounds cannot be treated within the time period for primary closure, or when a wound is infected, or exhibits oedema and sloughing, it is necessary to prepare the wound for periodic removal of devitalised and infected tissue; establish and promote adequate drainage; apply moist dressing and administer antibiotics.

Osbon (1969) states "In wounds involving the mandible, where there had been loss of osseous structure and involvement of the oral cavity, proper placement of a drain was most important." Care must be taken to place the drain superficially as deep drains have the tendency to cause breakdown of tissue with the formation of an oro-cutaneous fistula. Drains are removed in two to five days.

When a wound is suitable for closure, primary union is attempted unless of course there is an insufficient amount of tissue capable of being apposed. Under these conditions a local skin flap or a skin graft is used. Where there is a full thickness wound of the cheek and
when closure in layers would distort the tissue, or when, by necessity, closure is delayed, then it is useful to suture the skin to the mucosa. This procedure prevents further contamination of the wound and permits greater access to the oral cavity and fracture site.

Specific injuries - intra-oral wounds by their relative inaccessibility are sometimes overlooked. Particular attention should be given to lacerations of the tongue as bleeding may occlude the airway unless controlled. This is usually achieved by placing deep muscle sutures before suturing the superficial mucosal layer. In fact lacerations anywhere in the oral cavity should be closed if at all possible.

Gunshot wounds to the mandible fragment teeth, dentures and bone. These fragments require meticulous removal prior to wound closure. If there exists a full thickness wound of the cheek, a water tight mucosal closure is imperative to prevent breakdown of the tissue with formation of an oro-cutaneous fistula (Osbon, 1969).

Laceration of the parotid gland and duct may be treated in several ways. If the Stenson's duct is visible, the anastamosis of the severed ends may be accomplished over a polyethylene tube.

Kruger (1964) suggests the use of an intra-oral stab wound adjacent to the severed duct in which a rubber drain or polyethylene tube can be placed thus establishing a new duct opening. If these techniques
fail ligation of the proximal end of the duct may cause atrophy of the gland.

**Conclusion**

Three fundamental principles are pertinent to the successful management of soft tissue injury associated with a comminuted fracture of the mandible.

1. Meticulous wound preparation
2. Conservative debridement
3. Closure without undue delay

The information presented within this chapter is designed to cover 'Principles for the Primary Treatment' of facial wounds. Secondary reconstruction in itself is a broad field and generally falls within the field of plastic surgery.
The Management of Soft Tissue Injuries - References


BONE AND BONE GRAFTING

Part 1. - BONE

"Before considering the cellular processes resulting in the healing of a fracture or the utilisation of a graft, it is necessary to review briefly some features of the structure and behaviour of normal bone. Many of the changes occurring at the site of injury are no more than extensions of these normal processes" (Kramer, 1968, p615).

1. The Microscopic Structure of Bone

Bone is a calcified tissue of mesenchymal origin. Structurally there are two major components:

a) Cells

b) Intercellular substance (matrix)

Osteogenesis can be accomplished only in the presence of osteoblasts which are derivatives of the primitive mesenchymal cell (Provenza, 1964, p86). In the process of bone formation the osteoblasts become entrapped in their secretory product, the organic matrix. They are then called osteocytes. These cells are housed in elongated spaces or lacunae, from which radiate a number of minute canaliculi or tubules that contain slender protoplasmic projections of the cell body (Fig.8). The canaliculi and their contained cell processes are of great significance as pathways for diffusion, essential to the nourishment and survival of the osteocyte. Under the most favourable circumstances, nourishment of the
Fig. 8 - Note lacunae for the osteocytes and minute canaliculi (adapted from Bhaskar, 1962).
bone cell is rather precarious in that it is dependent largely upon diffusion. For this reason no osteocyte is more than a fracture of a millimetre from the nearest capillary (Ham, 1969, p389) Fig.9.

The organic matrix is composed of two chief constituents:

(i) Collagenous fibrils
(ii) Mucopolysaccharide cementing or ground substance

Once the matrix is produced, calcification is initiated, involving the deposition of mineral salts such as hydroxyapatite - $\text{Ca}_10 \,(\text{PO}_4)_6 \,(\text{OH})_2$ in the matrix. (Provenza, 1964, p86). This intercellular material, which is the product of cellular activity, determines the character and physical structures of bone.

2. **Types of Bone Tissue**

According to Kramer, there are three types of bone:

a) Lamellar bone
b) Woven bone
c) Bundle bone

a) **Lamellar bone** - refers to bone formed by the close apposition of matrix in the form of plates or lamellae. Collagen fibre bundles are situated within this matrix and are orientated parallel to each other and at right angles to the collagen bundles of adjacent lamellae. There are two distinguishable forms of lamellar bone.
Fig. 9 - Note the concentric arrangement of osteocytes around the central haversian canal (blood supply). (Adapted from Bloom and Fawcett, 1968).
Fundamentally they are identical in their anatomic and chemical make-up (Provenza, 1964, p88).

They are cancellous and compact bone. Within compact bone or haversian bone, as it is sometimes called, lamellae are arranged concentrically into units or haversian systems, the centres of which contain an haversian canal with its blood vessels. (Fig. 9)

Cancellous bone is characterised by the arrangement of thin delicate trabeculae with large marrow spaces intervening (Fig.10).

The trabeculae are lamellated, however, they are arranged in the form of flat plates or sheets and are rather delicate in comparison to the massive accumulations of lamellar rings characteristic of compact bone (Fig.11). Lamellar bone in its two forms comprises almost the whole of the adult skeleton.

b) Woven bone - contains coarse bundles of collagen fibres which are considerably larger than those of lamellar bone. These bundles are arranged in an irregular manner unlike the parallel arrangement found in lamellar bone.

Woven bone is spongy in nature and the trabeculae are finer and more closely applied than in cancellous bone. Owing to this fact, the radiographic appearance is somewhat different. Utilising intra-oral periapical radiographs, it is possible to distinguish individual
Fig. 10 - Note trabeculae and marrow spaces (adapted from Bhaskar, 1962).
Fig. 11 - Haversian bone characterised by the massive accumulations of lamellar rings (adapted from Bloom and Fawcett, 1968).
trabeculae of cancellous bone. This distinction is very difficult in woven bone, which is radiographically diffuse in appearance, owing to the dense trabecular arrangement. Bhaskar (1962, p178) uses the term "immature bone" and states that "such bone consists of more osteocytes per unit area than mature bone and these osteocytes are haphazardly arranged" (Fig.12).

c) **Bundle bone** - features stout collagen fibre bundles (Sharpey's fibres) inserted into bone substance from adjacent soft tissue and is referred to as bone of attachment, e.g. for tendons and periodontal membrane (Fig.13).

3. **Osteoid**

   This is uncalcified matrix (a protein carbohydrate complex) and is often referred to as prebone. With subsequent mineralisation, it is chemically transformed into bone. Osteoid is thickest where bone is rapidly forming or when there is a defect in calcification. Under most circumstances mineralisation occurs concomitant with, or immediately following, matrix formation (Provenza, 1964, p88). However, in areas of heightened cellular activity, matrix formation outpaces mineralisation, accounting for the increased amounts of osteoid at such sites.
Fig. 12 - Woven bone: more osteocytes per unit area than in mature bone (adapted from Bhaskar, 1962).
Fig. 13 - Bundle bone: bone of attachment (adapted from Bashkar, 1962).
4. **Bone Precursors**

The terms membrane and cartilage bone refer to the precursors of bone. Craniofacial bones are for the most part formed intramembranously. This variety of ossification is of the more primitive type and less complicated. Ossification occurs directly in connective tissue (mesoderm).

Cartilage bone is formed by endochondral ossification characterised by the formation and ultimate replacement of a pre-existing cartilage model. The long bones and vertebrae are results of endochondral ossification.

5. **Superficial and Deep Lining of Bone**

Covering the external surface of bone is an adherent membrane or periosteum. Ham (1969, p440) regards the periosteum as having two layers - an outer fibrous layer and an inner osteogenic layer. (Fig.14).

He also maintains that the fibrous membrane stripped from bone, which surgeons regard as the entire periosteum is in fact only the fibrous portion, and much of the cellular portion still remains on the bone surface. This fact accounted for many surgeons considering that the periosteum was either not osteogenic or that the elevated periosteum is responsible for bone reformation.

6. **The Process of Bone Repair**

The healing of a simple fracture serves to illustrate the basic principles of bone repair. The immediate
Fig. 14 - High power magnification of the periosteal layer. Note the outer fibrous layer and inner osteogenic cellular layer covering the underlying bone (adapted from Bourne 1956).
effects of injury are twofold:

(i) Direct traumatic injury to bone and adjacent soft tissue

(ii) Haemorrhage between fragments and into the surrounding tissue

On fracture, haversian blood vessels are torn, circulation eventually ceases in all vessels at the fracture site, back to a point of anastomosis with functioning vessels. In view of the precarious existence of osteocytes largely dependent upon nutrient diffusion via canaliculi and the relative lack of anastomosis between haversian systems, the death of osteocytes for a considerable distance either side of the fracture line is not surprising (Fig 15). Undoubtedly some cells are nourished by the diffusion of tissue fluids at the fracture site, however this favours only those superficial osteoblasts that line the marrow spaces at the fracture surfaces. Cells furthest away from the fracture site are least likely to survive, particularly those within the dense compact cortical bone.

In the vicinity of the fracture, within a short period - probably the first twenty-four hours, there is heightened cellular activity of the osteoblastic cells within the inner periosteal layer. Owing to continued active proliferation within this layer, new woven bone
Fig. 15 - The healing fracture (adapted from Ham and Harris 1956).
is formed. It is applied to the outer surface of the underlying cortex, on either side of the fracture line. This new bone is ultimately trabeculated and is called the cuff or external callus. Finally the two adjacent bone cuffs unite across the fracture site forming a bony continuum or sleeve around the fracture (Fig. 16). At the same time the external callus is forming woven bone, bone is also forming within the bone ends (internal callus). This is partly due to the activity of osteogenic endosteum and partly from those marrow cells possessing osteogenic potential. The endosteum is the connective tissue membrane lining marrow spaces and is equivalent to the periosteum.

What of the blood clot? Controversy exists as to the fate of the blood clot. Such material within soft tissue would be replaced by granulation tissue. However, organisation of the blood clot in a healing fracture, at least in some cases, does not occur. Instead it appears that the advancing internal callus gradually displaces the clot, subjecting it to absorption rather than organisation and replacement by granulation tissue (Kramer, 1969, p620). While the clot remains, danger of infection exists until it has been completely absorbed.

During the formation of internal and external callus, resorption and remodelling of the injured bone
Fig. 16 - Diagrammatic illustration of a healing fracture. Note the area of dead bone extending a small distance from the fracture site. (Adapted from Ham, 1965).
has been taking place, with the result that bone density is decreased on either side of the fracture line, a feature often discernible on radiographs. A greater portion of the external callus will be subject to resorption; however, the deeper layers will remain eventually to undergo final replacement with lamellar bone. For many years bone in the region of fracture is thicker than prior to injury.

Structural alterations of the internal callus proceeds, resulting in a bony structure, difficult to distinguish from the bone prior to injury. Healing is not always uneventful, particularly if infection supervenes. Treatment should aim to prevent delayed union or non union, the common cause being:

- infection
- inadequate reduction
- inadequate immobilisation

Infection is the major problem in bony repair because it interferes with the nourishment of the bone cell. To reiterate, such nourishment largely depends upon adequate blood supply and diffusion via canaliculi. With the added disadvantage of vascular disturbance from infection, many more bone cells die. Indeed, the relative avascularity of bone in contrast to soft tissue makes it comparatively inaccessible to defensive and repair mechanisms of the host and to antibiotics. When
infection occurs the body rejects the infected dying or dead bone by osteoclastic separation from healthy tissue. These separate entities or islands of bone sequestrate.

Under heavy antibiotic cover it is possible they become sterile and re-incorporated in some cases. However, when the mandible is comminuted and the fracture site is infected, despite heavy antibiotic administration, small fragments may still sequestrate. Under these conditions a bone graft using bone from another site and performed only after the signs and symptoms of infection have subsided, will be required if the defect is too large.

Inadequate reduction will delay union or result in non union, depending upon the size of the intervening gap. Large defects are incapable of being bridged by either internal or external callus. This predisposes to fibrous or non union. The presence of an excess of soft tissue between fracture surfaces is a mechanical barrier to the newly formed bone which is attempting to bridge the gap.

**Part II. - BONE GRAFTS**

A bone graft may be used to fill a defect in bone; to facilitate the healing of a fracture that otherwise would not heal, or in which healing would be greatly delayed. It is of particular use in the correction of residual deformity.
1. **Definitions**

A bone graft has been defined as a portion of bone removed from its site and inserted to repair a defect in another bone (MacNalty, 1961, p627). However, this is a limited definition as a bone graft may be performed using a portion of the same bone to repair a defect in that bone e.g. sliding mandibular bone graft.

The majority of bone grafts to the mandible are 'free bone grafts'. As the term implies, the grafted bone is detached completely from its original site and replaced at a new site in a one stage procedure e.g. iliac crest or rib graft to the mandible. Although the term free bone graft would not include a sliding mandibular graft, these are not frequently performed.

2. **Classification**

Most frequently bone grafts are divided into three categories:

1. Autogenous (Autograft)
2. Homologous or homogenous (Homograft)
3. Heterogenous (Heterograft)

If the donor is the recipient of the graft it is autogenous. If the donor is of the same species as the recipient, the graft is homologous. However if the donor is of a differing species the graft is said to be heterogenous.

These groups may be further sub-divided according
to the type of bone used for the graft e.g. cancellous or cortical bone or a combination of both. Often the graft takes its name from the donor site, such as an iliac, rib or tibial graft.

3. **Requirements of The Ideal Bone Graft**

According to Bell (1968) the ideal bone graft should possess the following properties:

1. Be a stimulant for osteogenesis
2. Be immunologically inert
3. Be rapidly revascularised and replaced by new bone

Autogenous cancellous bone with its large marrow spaces and numerous trabeculae, which in turn are lined by cells with osteogenic capacity, closely approaches this ideal. However, Roaf (1967, p426) states "Bone grafts in orthopaedic practice probably seldom, if ever, behave in this way and the majority of cells die; even the few which survive do not multiply. For practical purposes the graft can be considered as a scaffolding into which the mesodermal cells of the host grow, and on the surface of which they lay down new bone".

Autogenous bone probably possesses desirable chemical substances which stimulate osteogenesis.

4. **Indications for Grafting to The Mandible**

1. Loss of bony continuity from the original trauma, resultant infection, or surgery.
2. Correction of residual deformity to improve function and/or aesthetics.
Although aesthetics is not of primary concern, facial appearance is extremely important since disfiguring deformities have the potential for producing a serious social and psychological handicap.

5. The Fate of an Autogenous Bone Graft
   
   a) Vascularity of the graft bed

   Bell (1968) observed that the success of a bone graft is largely dependent upon two factors:

   1. The type of bone graft
   2. The vascularity of the graft bed

   Church (1959) states "The most important single factor in the success of any bone graft is the response of the host vascular bed". It appears that the graft functions primarily as a stimulus to osteogenic activity of the host bone (Bell, 1968). Weinmann and Sicher in 1955 (p335) noted, that a major portion of the graft died and was eventually replaced. Their conclusions were based on a concept of 'aseptic necrosis' in which large areas of dead bone are gradually replaced with vital host bone by a process of resorption and apposition. Mowlem in 1941, demonstrated the importance of a well vascularised graft site. Following the transplantation of bone into an avascular area, such as abdominal fat, the graft died. However following similar transplants into a well vascularised bed many cells survived. He concluded that the survival of bone cells
and the calcific structure of grafted bone depends largely upon the nourishment which the graft receives after transfer, rather than contact with living bone. Peer (1951) examined bone microscopically following a graft into tissue other than bone. He demonstrated that many bone cells of the graft survive, however, they lose their ability to maintain calcified intercellular structure, which is ultimately replaced by fibrous tissue. Following similar transplants into a bony defect it was found that a bone graft maintains its calcified matrix provided there is ultimate fixation of the graft to host bone, thus establishing a functional reason for its existence.

From the investigations of Mowlem and Peer, it seems the integrity and maintenance of a freshly transplanted autogenous bone graft depends primarily upon three factors:

1. An osseous graft bed (bone to bone - 'like tissue')
2. The vascularity of the graft bed
3. A functional use for the graft

b) **The graft cell**

Although it appears the graft bed is of prime importance to the survival of an autogenous bone graft, Church (1959) maintains osteogenic activity is not entirely induced from tissue at the graft site. He believes that new bone is regenerated from osteogenic
cells within the grafted bone. This may occur provided osteogenic cells survive the transplant, which would involve the interruption of blood supply to the graft. When a graft is cut from the donor site all circulation is abolished, for this reason cellular survival is likely on or near the outer surface of the transplant, or possibly in cancellous spaces that are reached rapidly by new vessels. Lining cells may survive because they are more readily bathed in tissue fluid at the graft site. Hunsuck (1969) states "a transplant that retains a portion of its periosteal covering and exposed endosteal tissue has the best chance of survival. However even under the most favourable circumstances the greater portion of the transplant will necrotise".

The initial survival of cells in any tissue graft depends upon two conditions existing at the site of transfer:

1. The cells must be bathed in an isotonic solution to prevent desiccation.

2. A fluid exchange must eventually reach the cells to provide them with nourishment and relieve them of accumulated waste products.

Cells of a cortical bone graft are less likely to survive because of the mechanical barrier to nourishment. An iliac cancellous graft, unlike cortical bone favours
nourishment because of its large marrow spaces. These marrow spaces present a greater surface area for fluid exchange necessary for the removal of accumulated wastes. Knowing this, it is reasonable to conclude that more cells will remain viable following a cancellous bone graft, and these cells may act as a source of osteogenesis.

c) Homografts

Although homologous bone may be useful for grafting because of its calcified structure, it does not have the qualities of fresh autogenous bone. Firstly, it contains foreign protein that may generate an inflammatory response, especially if multiple homografts are contemplated. Secondly, unlike autogenous bone, it offers no opportunity for 'focal osteogenesis'. However, Kramer (1968, p623) and Church (1959) suggest 'focal osteogenesis' is only a marginal factor to the success of a bone graft.

There are two main disadvantages in using homografts:

1. The absence of a suitable donor at the ideal time.
2. The possible transmission of disease.

'Immunological rejection' or incompatibility is not the usual cause for homograft failures. Freezing, freeze drying and irradiation considerably reduce the potential of 'transplantation antigens' inducing antibody production (Bell, 1968). Antigenicity is contained predominantly
within the bone marrow, for this reason homografts are washed of their marrow or rendered inert by one of the above processes. Burwell (1964) utilised a framework of homologous bone impregnated with fresh autogenous bone marrow. He found considerably more bone formed combining both components as compared to their separate use. Homologous bone washed of marrow and impregnated with fresh red marrow of the recipient, resulted in an osteogenic capability similar to an autogenous transplant of iliac cancellous bone. It appears that the homograft acts as a scaffold for the autogenous marrow and maintains the form and shape of the graft until it is replaced.

Experimental evidence presented by Richter and Boyne (1969) emphasized the osteogenic potential of bone marrow. They grafted autogenous marrow into mandibular defects and demonstrated its ability to actively promote osteogenesis.

d) Heterografts

Heterogenous bone is bone from a different species, for example Boplan®; a commercially available product which is a processed bovine bone.

Immunological testing of fresh bovine bone illustrated the major antigenicity was contained within the serum and red blood cells. Knowing this, efforts were made to lower the antigenicity of bovine bone by physiochemical means (Anderson and others, 1965). After the bone is subjected
to extraction by detergents and organic solvents followed by prolonged washing, sterilisation and freeze drying, it is enclosed in vacuum sealed sterile vials (Hughes & Gibson, 1968).

Numerous reports confirm that 'Boplan' performs well in oral and maxillofacial surgery in comparison with autogenous and banked bone (Anderson and others, 1965; Ellis, 1965; American Med. Assoc. Council on Drugs 1966). However, Bell (1968) failed to corroborate claims that it was equal or superior to fresh autogenous bone.

6. Reasons for Bone Graft Failure

Gaillie in 1931, enunciated three principle causes for the failure of a bone graft:

1. Infection
2. Inadequate vascularity of the graft bed
3. Inadequate immobilisation

Nisbet (1966) claims that regardless of what type of bone is used, a successful graft is dependent on the conditions at the site of grafting. Gillies (1968, p.544) and Mohanac (1969) outlined the conditions basic to the success of any bone graft.

i. All evidence of sepsis must have long disappeared at least for two or three months.

ii. No communication with the oral cavity is permissible. The risk of this occurring during the operation must be eliminated by the removal of teeth whose roots
might be exposed during the freshening of the bone ends.

iii. Scar tissue must be removed from the graft bed.

iv. Bone ends must be denuded of fibrous tissue covering.

v. Eburnated areas must be freshened with burs or rongeurs.

Intra-oral bone grafting is being used with quite some success, for elective procedures without pre-operative infection. Sailer (1974) presented the results of twenty-one mandibular resections followed by immediate intra-oral bone graft. In only one case was it necessary to remove the graft because of infection (osteomyelitis).

However, there seems little point in grafting intra-orally for comminuted fractures:

1. Access intra-orally is usually poor.
2. Under fracture conditions the wound is usually contaminated or infected.
3. Saliva contamination increases risk of infection and graft failure.
4. There is usually an extra-oral scar which requires revision and there is nothing gained by an intra-oral approach.
5. Securing the graft to proximal and distal fragments is simplified and generally more rigid when using a lower border wire. With an upper border wire there is an increased risk of ulceration and communication with the oral cavity thus giving rise to infection and loss of the graft.

7. Selecting DonorBone

Tibia, fibula, ilium and rib are the most common source of donor bone. Clinical experience has shown ilium and rib to be the most satisfactory.

In selecting donor bone one should consider the region in which the graft is to be placed. A cortico-cancellous graft from the inner and outer tables, or a half thickness section of the iliac crest and adjacent table, including the anterior superior spine, is ideal for replacing the ascending ramus, angle and a portion of the body of the mandible. (Fig.17)

When a large section of the mandibular body requires replacement a full or half thickness graft from the iliac crest is satisfactory. A full thickness graft offers greater strength and rigidity and may be indicated when these two requirements are desired. The anterior portion of the symphysis may be restored by using the greatest curvature at the height of the iliac crest. However, this is sometimes insufficient to restore extensive bone loss in this area. An alternative method of restoring
Fig. 17 - The ilium.
the symphysis can be achieved by sectioning through the anterior superior spine of the ilium, and excising the inner tables, producing a thick cortico-cancellous graft that can be inlaid between the lateral mandibular fragments.

The ilium is commonly employed as it offers an abundant supply of cancellous bone and its morphology is such that a cortico-cancellous graft of almost any size and shape can be taken. The importance of the cancellous portion cannot be over emphasised:

1. It is more readily revascularised and replaced than cortical bone.

2. It can act as a source of osteogenesis. The total area covered by periosteum and endosteal cells being greater than an equal amount of compact bone. Therefore it is desirable that a bone graft includes a cancellous portion as it is rapidly replaced by host tissue; an important factor in the success of any bone graft (Mowlem, 1941).

The ilium is by far the most important donor source for mandibular grafts. However in children under eight years old, the ilium does not offer sufficient bone (Bell, 1968). Rib offers a continuously regenerating source of bone as resected rib reforms within six months of surgery. Although pneumothorax may complicate this technique, its occurrence is rare. Complete bent rib has
been used to restore the symphysis; split rib for the
alveolus and restoration of contour. The technique
for reconstruction of the symphysis with bent rib is
well illustrated and described in Converse, 1968, p1030.
8. Some Techniques for Bone Grafting
a) Flint's method for obtaining bone

Dick, in 1946 observed that the transplantation of
bone chips from the iliac crest was the most effective
method of promoting osteogenesis, and thereby achieving
new bone formation. Flint (1964) states "Since its
introduction by Mowlem in 1942, autogenous cancellous
bone grafting of mandibular defects has become an
established method of achieving firm bony union in the
shortest possible time, but in spite of the obvious
advantages of the method there is still some reluctance
to use cancellous grafts. This stems from the general
impression that taking bone from the hip inevitably
produces considerable serious post-operative disability
which increases the patient's discomfort and time spent
in bed after the operation." However, it is possible to
obtain an adequate supply of cancellous bone with
minimal disturbance and discomfort to the patient.
Flint described a method he employed in the treatment
of thirty mandibular osteotomies and four cases of
delayed union. The following is a paraphrased outline
of his procedure:
A sand bag is placed under the outer side of the patient's right buttock to tilt the pelvis a little. After the standard preparation an incision of one inch was made along the anterior end of the iliac crest, about one inch behind the anterior superior spine (Fig. 18). This is immediately deepened down to bone and the edges of the wound retracted to expose the top of the crest. A small linear incision is made along the fibrous tissue and through the periosteum. A short transverse incision across the longitudinal cut serves to mark out a small cross (Fig. 19). The periosteum is elevated through this incision to about one square centimetre. Stripping of the muscle on the medial and lateral aspects of the ilium is not necessary, and in fact undesirable. It is muscle stripping that gives rise to post-operative haematoma and morbidity.

When the small area of iliac crest has been freed of its covering soft tissue, a 5 mm osteotome is used to outline the sides of a square of bone on top of the crest. The square of cortex is placed to one side and if not required in the grafting procedure it is replaced. The removal of the square lid of cortical bone gives access to cancellous bone within the iliac crest.

A small gouge is used to start the excavation of the soft cancellous bone and with this or a small Volkmann's spoon, the cancellous bone is taken from the
Fig. 18 - Modified incision for iliac crest exposure (after Flint, 1964).
Fig. 19 - The periosteal flap

Fig. 20 - The removal of bone chips from the internal surface of the ilium (after Flint, 1964).
inside of the iliac wing. The spoon and gauge can be passed backwards into the ilium to obtain bone as far back as the posterior iliac crest. The bone comes out in small chips or small curled pieces (Fig. 20). After bone is removed the cavity in the ilium is mopped out and packed with soluble gelatine sponge. The soft tissues are closed with catgut and the skin approximated with three or four silk sutures. It is rarely necessary to place a rubber drain for there is very little oozing from the resultant cavity within the ilium.

The bone which is taken from the hip is packed around the bone ends in the mandible to act as a soft cancellous chip graft. If stronger bone is required as a spacer between the bone ends, the small lid which is removed from the iliac crest at the beginning of the operation can be split and used as a strut. Healing is normally uneventful and the sutures are removed on the tenth day (Fig. 21).

Seventy percent of Flint's patients have sound clinical union by thirty-five days after insertion of the cancellous chip graft. The technique as described by Flint is useful only when small amounts of bone are required (about 20 cc of bone chips can be obtained using this method). With this indication in mind one can see distinct advantages for this conservative technique.
Fig. 21 - Post operative results following the standard exposure and excision (left).
Post operative results following the modified exposure by Flint (1 inch incision).
The performance of hip operations in the past have been limited by post-operative complications such as persistent neuralgic pain, paraesthesia, painful adhesions or tender scars. Haematoma formation which is so common following the normal hip bone graft procedures even when they are drained post-operatively is never a problem using Flint's method. However, paralytic ilius due to retroperitoneal haematomas is not an uncommon feature of the conventional hip operation. Bleeding post-operatively is more likely to occur following the extensive muscle stripping required to gain access to bone when using the conventional method. The complication of paralytic ilius is especially likely to occur when a bilateral hip procedure is undertaken.

The bone plate described by Flint (1964) can be shaped to fit the lingual defect and the remainder of the cavity can be filled with cancellous bone chips. Gillies (1968, p544) maintains the shaped or carpentered bone plate aids in splinting at the fracture site, and the cancellous chips aid or promote union. The use of block grafts from the tibia are now rarely used and has been largely replaced by cancellous or corticocancellous bone derived from the iliac crest.

Richter and Boyne (1969) point out that the transplantation of marrow or cancellous bone chips present particular problems. The foremost of these being the
maintenance of graft particles in position between the bone ends. This particularly applies to the transplantation of the so called 'mush' graft (bone marrow). A bone plate may hold the position of the fragments, however, the marrow graft being soft will tend to be displaced and lost from the graft site. To overcome this problem they adopted the use of a micropore filter supported by a vitallium network that was contoured to the lower border of the mandible.

The filter was designed to discourage the ingrowth of connective tissue. The vitallium mesh acts to maintain and stabilise the fragments. Richter and Boyne claim that bone marrow is truly osteogenic graft material, even more than cancellous bone chips, in that it presents a greater surface area in contact with host tissue. It also offers increased contact with tissue fluids and newly formed blood vessels. Furthermore bone marrow offers an abundant supply of osteoblasts and potentially osteogenic cells that will result in rapid bony union.

Gargiulo 1973, describes the use of a titanium mesh lined by a micropore filter and filled with iliac bone marrow for the successful treatment of a persistent non-union of the edentulous mandible. A seven month post-operative follow-up showed bone growth in the defect, no evidence of rejection of filter or mesh, and permanent restoration of facial symmetry. "Esthetic
contours are often difficult to establish with grafts of autogenous materials. Resorption and remodelling occur especially in autogenous grafts and the end result cannot be predicted with certainty" (Leake, 1974). He describes an implant tray which is useful to bridge large discontinuous defects in the mandible and to strengthen a comminuted mandible. The tray is a dacron mesh impregnated with polyether urethane elastomer to establish form and strength. Mandibular defects can be bridged using the tray which is filled with particulate autogenous bone.

Worley et al. 1973, stressed the difficulty in achieving adequate stabilisation of a rib used to span a large defect in the mandible. Intermaxillary fixation does not counteract the pull from the temporalsis muscle on the proximal fragment. This force, according to Worley et al., tends to place excessive strain on the wire ligatures fixing the graft. This fact, together with the initial resorption that takes place at the graft - host interface may result in instability of the graft (at least in theory). Excision of the coronoid process may be required to reduce the superior pull of temporalsis muscle on the proximal fragment. For these reasons Worley et al. recommend the use of a metallic mesh lined by a micropore filter and rigidly attached to the proximal and distal fragments by screws. The metal crib gives optimal stability to the graft.
b) The standard method for obtaining bone

The standard technique to obtain bone from the ilium is to accomplish exposure through an incision made over the iliac crest, which would extend posteriorly about four to six inches from the anterior spine. The incision is made through the soft tissues to bone at a point of contact with the origin of the gluteal and trunk muscles. Cortical grafts taken subperiosteally from the inner and outer tables or full thickness grafts including the crest, can be removed by the use of osteotomes, saws, burs, or any combination of these instruments. After removal of the graft cancellous bone can be obtained if more is required by curetting between the cortical plates. In order to preserve iliac crest contour, particularly in children, the crest can be fractured from below and raised in the manner of a trap-door with the muscles still attached. The graft is removed from the iliac table and the crest replaced (Mohnac, 1969).

The standard method is used when a large segment of corticocancellous bone is required, however, the method as described by Flint is a technique with much to commend it when grafting small defects.

c) Chip grafting with bone from the fracture site

Cohen, Feig, and Freeman (1968) in a paper on the management of comminuted mandibular fractures states
"There has been little reported about chip grafting techniques in which bone from the site of injury is used."

During World War II and the Korean conflict, maxillofacial injuries having severely shattered bone were treated successfully by using bone fragments already in the wound. Cohen, Feig and Freeman (1968) found that bone fragments already in the wound region act as chip grafts when placed under periosteum.

In 'civilian' practice healing proved to be accelerated when the wound was surgically cleansed and repacked with bone fragments from the site of injury.

Morgan and Szmyd (1968) utilised free injured bone from the fracture site to re-establish continuity of a comminuted mandible. Twenty-five of his thirty-one patients had satisfactory function within four months.

It has been shown that bone chips taken directly from a comminuted fracture site can be effectively used as a graft to restore a badly shattered mandible, provided that adequate fixation is achieved without undue delay. In most cases early treatment using all available bone fragments at the site of fracture will prevent nonunion, reduce healing time and the necessity for taking donor bone from another site.
Antibiotic therapy is essential for several weeks after any bone graft operation and should be continued if the wound shows signs of infection.

9. **Conservative Approach to Bone Grafting**

Huebsch and Kennedy (1970) state "so often the oral surgeon is inclined to place a bone graft, particularly if there is loss of substance, when a little patience, and a watch and wait attitude coupled with adequate fixation would perhaps allow healing".

Hinds (1962) claims that an extended period of immobilisation should be allowed in cases of non-union before a graft be placed. Brady (1966) reported healing of a fracture following a 1 cm bone loss, after an extended period of fixation and immobilisation.

Huebsch and Kennedy (1970), in order to demonstrate the ability of bone to bridge a gap, produced surgical defects in dogs. These varied from 3 to 18 mm. The mandibular fractures were fixed with plates and screws; no intermaxillary fixation was necessary. The results of this experiment showed that the degree of healing observed microscopically varied according to the width of bone that was resected. Union in the 3, 6, 9, 12 and 15 mm defects was solid. The 18 mm defect was clinically acceptable, however a band of fibrous tissue could be observed between the internal callus on microscopic examination.
These experiments indicate the need to allow an adequate period of immobilisation with adequate fixation before a bone graft is considered. Of course factors such as age, health, nutrition, infection and patient co-operation influence healing time.

10. A New Concept of Bone Healing Following Fracture

The classical concept of a healing fracture as presented by Kramer (1968, p619) requires revision in view of more recent information. Usually the fracture heals by the formation of an 'external callus' and 'internal callus'. This description is valid for those fractures in which there is less than rigid fixation across the fracture site. "If the fragments are fixed together so that movement in the fracture area is impossible, periosteal callus formation does not take place; at any rate this cannot be shown radiographically" (Brons and Boering, 1970). Fracture healing in these cases takes place by first intention, that is, marrow to marrow healing and what Kramer describes as internal callus. This is a process of endosteal bone formation and does not involve the formation of the sub-periosteal cuff (external callus). It is valid to assume that the formation of periosteal bone is a reflection of mobility (less than ideal fixation) at the fracture site. Absolute rigidity has been achieved by the application of lateral compression. Kline (1973), describes a
lateral compression system that produces rigid fixation at the fracture site, its aim being to promote rapid primary healing without the need for immobilising the mandible.
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THE CLASSIFICATION AND TREATMENT OF COMMINUTED MANDIBULAR FRACTURES

The diagnosis of a fractured mandible is adequately discussed in many well known texts dealing with the subject of maxillo-facial injuries, therefore, this aspect of care will not be considered in this thesis. However, it is relevant to clearly define what the author means by the term 'comminuted fracture' and to classify these fractures in relation to the mandible.

1. The Definition and Classification

The author defines a comminuted fracture as the presence of more than one fracture line at any given fracture site. The simplest example of this is, the triangular fragment sometimes seen at the lower border of the mandible (Fig. 22)

\Fig. 22 - The triangular segment at the lower border constitutes the simplest type of comminuted mandibular fracture.
Although the term is generally used when referring to a portion of bone that has fractured into many small fragments, this concept does not envisage the simplest form of comminuted injury.

Having defined the fracture, the next step is to classify this injury with particular reference to the extent of hard tissue damage, and to the presence or absence of serviceable teeth in the major segments of the mandible bordering the comminuted area.

Many descriptive terms have been used to portray the extent of tissue damage, for example:

- slightly comminuted
- moderately comminuted
- grossly comminuted
- severely comminuted
- avulsed fragments

It becomes obvious that the description of the extent of a comminuted injury is largely subjective. In order to minimise this subjectivity, the following classification which refers to the extent of injury is submitted.

A minor comminuted fracture - this is characterised by the presence of one or two small fragments in the area of fracture. There is usually minimal displacement and little soft tissue disturbance. This type of comminuted injury is typically seen as a result of 'civilian' trauma such as assault or automobile accident.
Refer to Fig. 23.

A major comminuted fracture - this fracture is most frequently the result of extremely violent impact such as from a bullet, a grenade or an exploding mine. Typically it is a war injury and rarely seen in civilian life. The hard and soft tissues are grossly disorganised or even avulsed. This injury is often characterised by the presence of a penetrating entry wound and an explosive exit wound. As a rule there are numerous small comminuted fragments, sometimes as many as ten. Some of these fragments will be greatly displaced. The mandible is grossly fragmented (Fig. 25).

A moderately comminuted fracture - this falls somewhere between the minor and major type of comminuted fracture and rarely is there more than five fragments of comminuted bone. Soft tissue damage is generally not as extensive as does occur in the major comminuted injury (Fig. 24).

After grouping comminuted fractures of the mandible according to the extent of injury sustained, the next stage in the classification is to consider the presence or absence of serviceable teeth in the major fragments. This is desirable because it has a practical relationship to the management of the fracture.
Fig. 23 - Examples of a minor comminuted fracture.

Fig. 24 - Examples of a moderately comminuted fracture.

Fig. 25 - Examples of a major comminuted fracture.
Type I comminuted fractures - teeth are present on either side of the fractured area. They can be used as a guide to reduction and for immobilisation (Fig. 26).

Type II comminuted fractures - teeth are present on one side of the fracture only and can be used to immobilise the tooth bearing fragment. Teeth may also be effective in holding the edentulous fragment by means of an appliance (Fig. 27).

Type III comminuted fractures - The patient is edentulous either from the accident or previous to it (Fig. 28).

By unifying the first classification (which is based on the extent of injury) with the second type (which is concerned with the distribution of available teeth and relates to methods of fixation and immobilisation) one can give a practical classification to all comminuted fractures involving the ramus and body of the mandible. Isolated comminuted fractures of the condyle should be considered separate to this classification unless there is concurrent involvement of the ramus. Consider the examples of the unified or full classification (Figs. 29, 30, 31).
Fig. 26 - A Type I comminuted fracture.

Fig. 27 - A Type II comminuted fracture.

Fig. 28 - A Type III comminuted fracture.
Fig. 29 - A minor Type I comminuted fracture
(Type I - minor comminution)

Fig. 30 - A moderate Type II comminuted fracture
(Type II - moderate comminution)

Fig. 31 - A major type III comminuted fracture
(Type III - major comminution)
From the review of the literature it became apparent that no classification of comminuted fractures had been previously described and that there was a real need to do this. A clear clinical description of the injury afforded by a classification is especially useful if such a classification helps in determining the line of treatment to follow. The author believes the classification submitted will assist the clinician in deciding the type of treatment he will select.

With these points in mind, the author has developed the classification presented in this thesis.

2. **The Principles of Treatment**

The basic principles essential to the successful management of a comminuted mandibular fracture are:

1. Stabilise the major fragment or fragments adjacent to the comminuted area (early immobilisation).

2. Establish prophylactic drainage in all gunshot type comminuted injuries and major comminuted injuries of the 'civilian' type.

3. Retain comminuted fragments when at all possible.

4. Following careful debridement and irrigation obtain a tight soft tissue closure in the area of commination.
The overriding principle is to stabilise the major fragment or fragments bordering the comminuted area. Stability is a problem in some cases and is influenced by several factors.

1. The availability and distribution of suitable teeth.
2. Muscle action on fragments (both major and comminuted).
3. The extent of hard and soft tissue damage.
4. The locality of the fracture.
5. The availability of specialised appliances.
6. The conditions under which the surgeon has to operate, e.g. war zone, improvised conditions.

After having stabilised the major fragments, the comminuted fragments in some cases can be manually manipulated into adequate alignment or left passively within their soft tissue envelope. Provided the comminuted fragments are not greatly displaced, the influence of soft tissue may be sufficient in some cases to bring about reduction. On this point Kelsey Fry and Ward (1956, pl56) state in reference to the soft tissue reduction of comminuted fragments at the lower border, "Such improvement almost invariably occurs and is probably due
to the contraction of fibrous tissue in the surrounding soft tissue wound. It would, for example, be a mistake to attempt to replace such a fragment by a circumferential wire". A similar situation does sometimes arise with fractures at the angle and ramus, in which case the comminuted fragments return under the influence of the masseter and medial pterygoid muscles to a satisfactory position for healing to occur. The major fragment is of course immobilised.

Whenever possible an open reduction procedure should be avoided as further disturbance to the comminuted bone will compromise an already reduced blood supply and thereby jeopardise vitality of bone. However, the co-existence of a full thickness soft tissue wound may enable direct access to the comminuted bone.

If there is minimal displacement of the comminuted fragments, or if these fragments can be stabilised by interdigitation without recourse to stripping soft tissue attachments, and provided the major fragments can be well stabilised, soft tissue closure alone should be performed.

An 'open' procedure as a routine approach to the management of these fractures is not justified, particularly if a conservative 'closed' procedure will achieve an acceptable aesthetic and functional result. However, direct bone wiring is indicated when displacement is gross;
when muscle tends to distract fragments; when soft tissue interposition prevents reduction and when fragments cannot be stably interdigitated.

All bone in the comminuted fracture area should be retained and only those fragments that are washed 'free' after vigorous irrigation with saline should be removed, if at all. The routine removal of 'free' bone is an unwise practice as under the protection of an antibiotic and provided any intra-oral wound is closed to achieve a watertight seal, the detached fragments can be retained in the wound so as to act as a 'chip' bone graft. This bone will contribute ultimately to the structure of the mandible. If there is doubt as to the removal of 'free' bone from the site of fracture the following principle is suggested: if the removal of a detached or almost completely detached fragment from the site of fracture would produce a bony defect except of a most minor nature, then it should be retained so as to act as a scaffold and a stimulus to osteogenesis. Large defects in bone are incapable of being bridged by the normal healing process and ultimately will lead to non-union or fibrous union.

Major comminuted fractures are prone to become infected, especially those resulting from a gunshot. Being aware of this fact Awty (1975) and Kelsey Fry and Ward (1956,p95) recommend the routine insertion of a 'prophylactic drain'. The assumption, and indeed the fact, is that pus frequently develops and unless drainage is immediate
there is an increased risk of sequestration even when treatment is not delayed. Awty (1975) says without exception he inserts a drain for all gunshot comminuted fractures of the mandible.

It is extremely easy, especially when pus is discharging from a drain to assume that some comminuted fragments are sequestra. This diagnosis is disastrous and sequestrectomy may lead to non-union. The proper way is to allow bone fragments to sequestrate naturally with the exception of larger fragments that are prevented from passing down the fistulous tract. Under these conditions the sequestrum can be removed with a pair of small haemostats.

The diagnosis of sequestration is not merely the presence of pus and a comminuted fragment, but the obvious clinical process characterised by the appearance of bone at a tissue surface. Radiographically the diagnosis of sequestration of comminuted fragments is extremely difficult and conservatism at this stage may obviate the need for a bone graft at a later date.

3. **Methods of Treatment**

Since the Great War, numerous methods for the fixation and immobilisation of fractures have evolved. The facial injury of greatest consequence was the comminuted fracture either involving the mandible or maxilla or both.
Certainly the incidence of comminuted fracture of the mandible in the military combat situation is significantly high as to make this type of fracture the 'rule' rather than the exception (Author's view from statistics taken from Alling 1974).

In civilian life the incidence of comminuted injury involving the lower jaw is very low (3 cases per 200 maxillofacial fractures). I refer the reader to the section dealing with statistics.

Most methods used in the routine management of mandibular fractures can be applied to the treatment of comminuted fractures of the mandible. Frequently, the simplest methods are the best and there is no point in making a straightforward procedure an elaborate exercise; although sometimes unusual methods may be needed to treat a comminuted mandible.

a) Arch-bars

The author refers the reader to the following articles which illustrate the successful use of arch bars in the treatment of comminuted mandibular fractures (Calhoun 1958, Cohen, Feig and Freeman 1968, Parker 1949, Atterbury 1960 ................., Crowe 1953, Bradley and Bonette 1955 and Donohue 1963).

Paul (1968) states "The disadvantage of the continuous arch bar technique is that it is not applicable where there has been loss of bony structure,
as in patients with gun shot wounds, or if the fracture is not anatomically reduced. The continuous arch bar should fix a reduced fracture, but it should not be applied to keep fragments apart*. This statement is most relevant as the majority of comminuted lower jaw injuries are the result of a military weapon frequently producing complete or partial avulsion of a segment of the mandible.

Compound comminuted fractures of the mandible often present fixation problems when using arch bars because of the loss of available teeth and bone. However, arch bars can be applied when specialised laboratory facilities are unavailable for the making of cap splints, and where there is minor comminution, minimal displacement, little or no bone loss and an adequate number and distribution of suitable teeth in the major fragments. Thus the arch bar is suited to a minor non-avulsive comminuted fracture of the civilian type. Although, many would disagree with placing such a limitation on the use of arch bars, the fact remains that the degree of rigidity necessary to counteract torsional stress is lacking. Cap splints, external pin fixation and metallic mesh can be used as a reliable alternative.

b) **External pin fixation**

This procedure gained popularity in Great Britain during the Second World War, as it was realised that external pin fixation had an extremely important role to play in the early management of comminuted lower jaw fractures.
Converse (1964, p478) makes the following statement, "If external pin fixation has a place in fracture management, it is in the control of the edentulous proximal fragment with extensive comminution at the fracture site". Pins placed in this area will resist the action of the elevator muscles until consolidation of the comminuted fragments has been established.

Pin fixation is not absolutely rigid and frequently requires supplementary intermaxillary fixation during the first few weeks of healing. At best pins will remain in position giving an adequate control of the fragments for two months (Kelsey Fry and Ward, 1956, p198).

Some of the indications for external pin fixation as listed by Rowe and Killey (1968, p89) are:

1. Gross loss of bone substance at the site of fracture.
2. Osteitis or local osteomyelitis at the fracture site.
3. Battle-field casualties (operative time, facilities are limited).
4. Poor risk patients.
5. When immediate movement of the mandible is desirable.
6. Urgent control of the collapsed symphysis.
7. Control of fragments during the reconstructive bone grafting procedure.
Rowe and Killey (1968, p. 90) by the following statement emphasise the speed and applicability of pin fixation for urgent treatment of comminuted fractures—"When, for example, the lower anterior teeth are standing in otherwise edentulous upper and lower jaws, and a bilateral comminuted fracture or a through-and-through gunshot wound has occurred in the angle region, posterior collapse of the symphysis will demand urgent control of this fragment. This can be rapidly achieved by the insertion of one, or preferably two, screw pins under local analgesia, and connecting these rods and universal joints to a plaster headcap and metal framework".

Although in the civilian environment external pin fixation has fallen into disfavour, it obviously has a major role to play in the management of battle-field jaw casualties. Waite (1967) described an appliance that was light, neat and inexpensive. This is the bi-phase pin appliance which has a quick cure acrylic resin connecting mold. The bi-phase appliance was used with success in treating comminuted mandibular fractures in Vietnam.

The following authors deal with most aspects of external pin fixation (Hamer 1970, Khedroo 1970, Down 1972). Probably the most important single point that requires emphasis, because it is a major factor contributing to the loosening of pins, is the electrochemical instability of the implanted metal. Down (1972)
considered the problem of premature loosening of pins to be chiefly the result of electrochemical instability and not load as previously thought. Stainless steel pins placed under load will invariably loosen, however, titanium pins under the same conditions rarely if ever loosen prematurely. He claims that stainless steel is very unstable in comparison to titanium and breaks down electrochemically to form two toxic substances, nickel and chromium. It is obvious that for those cases requiring long periods of fixation stainless steel appliances should not be used.

c) Circumferential wiring

This is particularly useful in the management of a comminuted fracture of the edentulous mandible.

Thoma (1969, p543) lists indications for circumferential wiring. Those indications related to the treatment of a comminuted fracture are listed as follows:

1. Fragments with triangular segments at the inferior border. (Minor comminuted fracture)
2. Comminuted fractures with longitudinal fragments.

Atterbury and Panagopoulos (1959) successfully managed a comminuted fracture of the lower jaw with circumferential wiring and acrylic splints. The patient was three years old.
Fig. 32 - A comminuted fracture of the mandible with longitudinal fragments successfully reduced with a circumferential wire (After Thoma, 1969).
In the edentulous patient with a comminuted fracture the application of a circumferential wire is not intended to reduce and stabilise the comminuted fragments or fragment per se, but to stabilise the adjacent major fragments to the splint. Under some circumstances, the reduction and fixation of the major fragments to the splint, can be combined with the reduction and fixation of the comminuted fragments, particularly if there is a longitudinal piece of bone at the lower border of the mandible (Fig. 32).

If there is a bilateral comminuted fracture such as the through-and-through gunshot wound, the fixation of the major fragments is frequently difficult using circumferential wires and an acrylic splint exclusively. The horse-shoe shaped anterior segment tends to 'bucket handle' under the influence of the infra-mandibular musculature. The need for a combination of techniques becomes apparent.

d) **Mesh fixation**

Several authors recommend the treatment of continuity defects and comminuted fractures of the mandible with some form of mesh as an internal fixation appliance. Despite the obvious criticism for using mesh as a fixation appliance in treating potentially septic comminuted fractures, particularly battle field casualties, this form of treatment is gaining popularity (Bear et al 1971, Leake

Bear et al (1971) state that stainless steel mesh is useful when more conventional means of management are not effective such as for the "reduction and stabilisation of comminuted fractures of the mandible". He presents a few cases of comminuted mandibular fracture successfully treated in this fashion.

Joy (1973) states "If there is destruction and avulsion of large segments of the mandible or maxilla, the remaining segments should be stabilised in as close to their anatomical relationship as possible ". He goes on to say "We have found that small structures of stainless steel mesh have accomplished this task with good result ".

Cuttino and Green (1972) on the immediate management of facial gunshot wounds state "It has been our experience that those meshes that become exposed during the post-operative period can be maintained by meticulous wound care and that a granulating wound will gradually close intraorally or will provide a good granulation tissue bed for external skin grafting procedures ".

There is no doubt that a mesh framework can be used
with great success in the reconstructive phase of treatment for the fixation of major fragments, for the maintenance of space between fragments and for the acceptance of a particulate bone graft. However, it is the author's view, that despite the few recent reports of the successful management of comminuted avulsive gunshot injuries utilising mesh as a fixation appliance, there are the following risks:-

1. Prolonged infection
2. Sequestration of the mesh
3. Prevention of sequestration of infected dead or dying bone contained within the mesh.

The apparent successes reported from Vietnam may be attributed in part to antibiotic therapy and in particular to meticulous wound toilet and debridement. On this aspect of treatment Joy 1973, says that four to six litres of saline solution are used pre-operatively for proper wound toilet and debridement.

e) Bone plates

Bone plates are most frequently placed on the buccal cortex, however, they can be used effectively on the lower border. The main advantage of the plating procedure is the very rigid fixation of the fracture, in many cases obviating the need for intermaxillary fixation. However, the application of bone plating to the treatment of comminuted mandibular fractures is
limited. Frequently the comminuted area is such, that it is not possible to span the fracture and place screws in sound bone. The danger of infection is always present.

Many forms of bone plating have been suggested and it is difficult to see how these can be applied in any but the most minor comminuted fracture (Schilli and Nuderdellmann 1974—dynamic compression plate; Getter et al 1972—biodegradeable plate; Robinson and Shuken 1966—the L splint). Certainly, as an alternative direct bone wiring is preferable because of the minimal bulk of foreign material implanted within tissue. Despite the limitations, bone plates are occasionally used in the treatment of comminuted fractures of the mandible (Fig. 33).

f) **Direct bone wiring**

Already, this topic has been discussed within this thesis in the section dealing with the 'principles of treatment'.

When direct internal fixation is indicated, this is usually the method of first choice. The obvious advantages are:

1. Minimal apparatus
2. Ease of application (flexible procedure)
3. Minimal implantation of foreign material
4. Ease of removal if required.
Fig. 33 - A comminuted fracture stabilised with a bone plate in conjunction with inter-maxillary fixation (acrylic splint) and direct wiring of comminuted fragments (Courtesy of Dr. J. Cumming).
Rowe and Killey (1968, p103) are of the following opinion, "Complex comminuted fractures, particularly those which are compounded externally through a skin wound suitable for primary closure, should be treated by transosseous wiring since direct access to the bone is already present and accurate apposition of the bone fragments is desirable ". However, fractures which are compounded intra-orally should be treated with some degree of reserve, as there is a definite risk of organisms from the mouth tracking into the fracture site and causing infection. Any metal, be it wires, plates or mesh, if present in the site of infection will usually perpetuate that infection and prevent healing. Most often the surgeon is prepared to take a risk provided the oral mucosa can be closed to achieve a water tight seal, provided fracture treatment has not been delayed and provided antimicrobial agents have been administered as a prophylaxis against developing infection.

If treatment is delayed or if there are signs of wound infection developing, the implantation of foreign material such as a bone suture especially wire, should not be considered. However, after all signs of infection have subsided and if direct bone wiring is required it should be undertaken.
Frequently direct bone wiring alone is insufficient to maintain stability of the comminuted and major fragments without some form of intermaxillary fixation. Curtright et al (1971) describes fracture fixation using a biodegradable material, polylactic acid. Macaca rhesus monkeys were used in an experiment in which polylactic acid sutures were used for internal fixation of bone fragments. The result of this study indicated that polylactic acid sutures degrade slowly but do not interfere with bony healing. This material would eliminate the need for a second surgical procedure, which is sometimes required for the removal of stainless steel wires that have proved incompatible.

There have been reports of comminuted fragments being suspended from an arch bar as illustrated in Fig. 34. Although this procedure is of use in attempting to re-establish a badly comminuted symphysis, the risk of infection tracking down the wires into the wound is ever present. The prime advantage of this technique is to prevent gross displacement of comminuted bone fragments by the unrestricted action of the genioglossus, geniohyoid and digastric muscles.

g) Transfixation

This method of fracture fixation has fallen into disfavour, however, it may prove to be a useful alternative when other methods are of little use.
Fig. 34 - Comminuted fragments suspended from an arch bar type arrangement as proposed by Kazanjian and Converse (1974).
**Fig. 35** - The extent of bone injury and the fixation scheme employed by Bromidge (1971).

**Fig.**

Extent of bone injury.

Fixation scheme employed $x, y = $ Kirschner wires, $z = $ splint.
Bromidge in 1971 presented a most interesting case and made this statement, "The treatment of comminuted fractures of the mandible, especially when externally compound, can present a considerable problem. On occasion a less conventional form of treatment can be used to advantage". He described a severe compound comminuted fracture of the mandible in which Kirschner wires were used to control the major bone fragments and provide continuity across the area of comminution (Fig. 35).

The anterior part of the mandible from about the second premolar to the second premolar was extensively comminuted. Between the major fragments there were several comminuted fragments with surrounding soft tissue attachment. A 2 millimetre diameter stainless steel Kirschner wire was passed transversely through the two posterior fragments. The wire passed just above the lower border in the molar regions, transfixing the deep musculature of the tongue. The major fragments were adjusted on the wire and prevented from lateral displacement by bending the wire at right angles on the buccal side of the bone.

A second Kirschner wire was required to provide structure and form for the U shaped anterior segment.
This was driven into the medullary cavities just above the cortical plate of the lower border. In the case described, all the elements of the lower border were present, although with only a tenuous soft tissue attachment. For this reason Bromidge made no attempt to link comminuted fragments directly together by transosseous wires as this would jeopardise their survival. The soft tissue and comminuted fragments were sutured to the Kirschner wire without actually handling the bone itself, thus avoiding further stripping of the vascular soft tissue attachments.

The transverse Kirschner wire served two purposes viz, to prevent lateral displacement of the posterior fragments and to prevent retroposition of the tongue, which would restrict the oral airway.

The U shaped Kirschner wire acted as a frame to which comminuted bone could be stabilised and to which the digastric, geniohyoid and genioglossus muscles were attached until the mandible consolidated. These muscles will ultimately re-attach to the newly formed bone.

Another useful method to control the comminuted symphysis, is to ligate the soft tissues of the floor of the mouth anterior to the tongue, and fix the ligated mass to an extension rod which is secured to cap splints on the major posterior fragments.
h) **Cast splints**

Cast metal splints can be used to great advantage in the treatment of a comminuted fracture of the mandible provided there is an adequate distribution of a few useable teeth.

The major advantage of this type of fixation-immobilisation appliance, is the degree of rigidity it imparts to the major fragments. Torsional stress is resisted, space between fragments can be maintained if required, and the jaw can be immobilised using the splint. Cap splints produce a very rigid fixation even if only one tooth is present on a fragment.

A comminuted symphysis is ideally suited to the application of cast metal splints, provided there are teeth in the major posterior fragments. Under these circumstances the tendency for the dental arch to contract can be resisted by a connecting metal arch. Furthermore, the tongue collapse and posterior displacement of the comminuted bone fragments can be prevented by ligating with wire, an adequate amount of lingual tissue and securing it to the arch.

In the extensive comminuted jaw injury necessitating a prolonged healing period or extensive reconstructive surgery, the splint can be designed to aid in the reconstructive phase and maintain fragments rigidly in a fixed position.
i) Bone clamps

In the past, bone clamps have been used on occasion for the treatment of mandibular fractures. However, not until recently has any attention been given to the use of an 'active compression appliance'. Kline in 1973 described the use of a lateral compression plate that maintained a constant compressive force across the fracture. The acclaimed benefits of rapid bony union and the elimination of intermaxillary fixation has been supported by Brons and Boering 1970, and Boyne and Morgan 1972.

The lateral compression plate is a form of direct internal fixation, however, it is not applicable to the management of a comminuted mandible. A clamp of sufficient dimension to span the comminuted fracture area would be of such size as to preclude its use in most cases.

j) Eyelet wires

A comminuted mandibular fracture generally requires a longer period of immobilisation than does a 'simple' fracture, and stabilising the major fragments is sometimes a treatment problem.

Eyelet wires are useful for the emergency immobilisation of the mandible, however, they are of little value in preventing bucco-lingual rotation of the major fragments and when a long period of stable
fixation is required.

Probably the only indication for the use of eyelet wires for this type of fracture, is to immobilise a unilateral minor comminuted fracture with serviceable teeth on the major fragments.

4. **Comminuted Fracture of the Condyle**

The diagnosis of an intra-capsular comminuted fracture is based upon correlating all information obtained from a history, physical examination, visual findings and radiographs. The obvious clinical features to expect are pain and swelling over the involved joint, limited movement and 'gagging' occlusion.

The degree of limited movement will depend on the extent of muscle spasm, oedema, haematoma and mechanical obstruction (MacLennan, 1969).

a) **Treatment**

The bulk of information on the treatment of comminuted fractures of the condyle is to be found in Rowe and Killey 1968, and even in such a monumental work it barely receives mention.

The extreme paucity of literature on this particular type of comminuted fracture reflects the rarity of its occurrence. Indeed, it is a very rare fracture but not an insignificant injury because of the possible complications that can arise.
In reference to the treatment of a comminuted condylar fracture Rowe and Killey (1968, p162) make the following statement, "Comminuted fractures of this area, not involving the articular surface of the condyle, do not present any special problem and union occurs readily. When the articular surface is involved, or where the fractures are compound, early movement must be instituted to prevent ankylosis ".

Thoma (1938) states "Ankylosis of the jaw may follow traumatic injury, although it is more frequently caused by infective arthritis, otitis media, and osteomyelitis of the ramus ". He goes on to say," "We therefore find ankylosis resulting from a variety of traumatic injuries, the immediate causes, however, are interarticular haemorrhage, comminution of the joint, and secondary infection ". Ankylosis frequently follows comminution of the interarticular meniscus or its destruction by secondary infection (Thoma, 1938).

Injury to the joint may be direct or indirect. Direct injury is frequently compound and prone to become infected. In very severe compound joint injuries all non-viable bone should be removed before closure of the wound (Rowe and Killey, 1968, p162). Treatment for a comminuted mandibular condyle is summarised according to the methods as outlined by Rowe and Killey (p165).
<table>
<thead>
<tr>
<th>FRACTURE</th>
<th>TEETH</th>
<th>NO TEETH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral</td>
<td>immobilisation</td>
<td>no immobilisation</td>
</tr>
<tr>
<td></td>
<td>2 weeks</td>
<td></td>
</tr>
<tr>
<td>Bilateral</td>
<td>immobilisation</td>
<td>immobilisation</td>
</tr>
<tr>
<td></td>
<td>3 weeks</td>
<td>3 weeks</td>
</tr>
</tbody>
</table>

The period of immobilisation should be minimal and "It is this emphasis on function which is important with fractures involving the temporomandibular joint, for unduly prolonged immobilisation creates complications" (MacLennan, 1969).

The author suggests treatment along the following lines:

1. **Conservative treatment first**
   A short period of immobilisation is desirable in dentulous cases in order to prevent shortening of ramus height and the development of an anterior open bite. This treatment must be followed by active movement and a series of corrective jaw exercises.

2. **Other treatment**
   If there is a progressive diminution in the range of mandibular movements, particularly the degree of hinge opening, a condylectomy is indicated as fibrous or bony ankylosis is probably developing.
A grossly compound comminuted joint should be debrided of all non-viable bone, in fact judgement may dictate that an immediate condylectomy is required. The risk of bony or fibrous ankylosis is high, especially if the wound becomes secondarily infected.

Despite adequate treatment of a comminuted injury to the temporomandibular joint, complications can arise.

- Arthrosis
- Traumatic arthritis
- Subluxation of the other joint
- Restricted movement
- Deviation
- Ankylosis
- Open-bite deformity
- Asymmetry

Treatment of these complications are many and varied and would include one or more of the following:

- Physiotherapy
- Short wave diathermy
- Occlusal rehabilitation
- Condylectomy
- Condylotomy
- Menisectomy
- Arthroplasty
- Intra-articular injections of sclerosing solution (subluxation)
Osteotomy

Ostectomy

b) Rehabilitation of condylar fractures

"A patient who has sustained a condylar fracture cannot be considered cured until he is able to masticate easily with the contralateral side of the dentition, which implies the recovery of condylar excursion" (Gerry, 1965).

All patients should remain under treatment until there is a gliding condyle and contralateral mastication. Also the patient must understand the nature of the problem and his role in correcting it. Excessive lateral deviation can be corrected if the patient practices hinge opening and closing, whilst holding the tip of the tongue against the lingual alveolus on the side opposite the deviation. Numerous devices have been used to correct this deviation, however, a clear explanation of the problem to a willing patient, prepared to perform the prescribed exercise, and prepared to practice unilateral mastication on the side opposite the deviation, will soon return to normal function.

If an anterior open bite develops following mobilisation of the jaw, a further period of inter-maxillary fixation is required. However, despite this
additional period of immobilisation, a open bite
deformity may persist. When this deformity is function-
ally and aesthetically unacceptable, and if it cannot
be corrected by conservative means, then a mandibular
osteotomy is required to re-establish normal occlusion.
The Classification and Treatment of Comminuted Mandibular Fractures - References


2. Awty, M. - Personal communication, Nov. 7th, 1975.


THE PREVENTION AND TREATMENT OF POST-OPERATIVE COMPLICATIONS

Post-operative care is a very important part in the overall management of the comminuted fracture patient. Fortunately, "Post-operative complications are unusual at the present time, and the comparative freedom enjoyed in this respect is largely due to the careful employment of chemotherapy and antibiotics" (Rowe and Killey, 1968, p180).

However, post-operative infections must be anticipated and according to Archer (1966, p895) cellulitis and osteomyelitis represent the most frequent complications of fractures of the mandible.

1. **The Immediate Post-Operative (Anaesthetic) Period**

The primary concern during the recovery period following a general anaesthetic is the maintenance of a clear airway.

For the majority of 'civilian' comminuted mandibular fractures simple measures such as:

1. Adequate regular suction
2. Posture
3. Tongue suture
4. Nasopharyngeal tube
5. Lubrication of the lips

are effective in preventing occlusion of the oral and nasal airway during this period. These precautionary
procedures must be maintained until the fracture patient has regained full consciousness and the protective cough reflex.

The decision to undertake a tracheostomy at the time of surgery as a precaution against post-operative respiratory distress, is a matter for individual case assessment. Certainly deep penetrating wounds involving the floor of the mouth, the tongue and the pharynx will generally require tracheostomy because of the risk of obstructive oedema developing in the oropharyngeal region. I refer the reader to Chapter 1, section 2, on the airway.

At the bed-side the following instruments must be present in the event of a respiratory emergency developing

1. Wire cutters - taped to the bed head are an essential if the jaws are immobilised.
2. Clements or other adequate suction apparatus
3. Mouth prop
4. Tongue forceps
5. Tongue depressor
6. Swabs and swab holder
7. Oral airway
8. A selection of Bronchial catheters
9. Torch
10. Accessible supply of oxygen
11. Rapid access to a tracheostomy tray
An increasingly popular method of maintaining and controlling the post-operative airway is to leave in situ the naso-tracheal tube for twenty-four hours. During this period the patient is kept sedated with valium and omnipon or morphine. This technique must be carried out in the intensive care unit as the patient requires careful monitoring and ventilating as required.

Restlessness may be a sign of respiratory distress and not attributable to post-operative pain. It is therefore essential that the nursing staff and those involved in the treatment of the patient are alerted to this fact. In the majority of cases the fracture patient does not complain of post-operative pain, however, restlessness due to pain may be alleviated by the administration of pethidine, 50-100 mg. subcutaneously. Pethidine has a slight respiratory depressant action and some surgeons prefer the combination of pethidine and nalorphine hydrochloride. Nalorphine hydrochloride counteracts the slight respiratory depressant effect of pethidine.

Routine post-operative sedation is not usually required, however, in the event sedation is needed to control restlessness, anxiety and promote sleep, a drug should be selected that does not depress respiration and the laryngeal reflex to any appreciable extent. Three drugs best suited to this task are paraldehyde, valium and nitrazepam.
Average Adult Hypnotic Doses of Non-Barbiturates

<table>
<thead>
<tr>
<th>Official Name</th>
<th>Proprietary Name</th>
<th>Dose</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraldehyde</td>
<td>same</td>
<td>5-10 mls.</td>
<td>widest margin of safety.</td>
</tr>
<tr>
<td>Diazepam</td>
<td>Valium</td>
<td>10-20 mg.</td>
<td>wide margin of safety.</td>
</tr>
<tr>
<td>Nitrazepam</td>
<td>Mogadon</td>
<td>5-10 mg.</td>
<td>wide margin of safety.</td>
</tr>
</tbody>
</table>

"Paraldehyde has a wider margin of safety than any other hypnotic, since therapeutic doses (except i.v.) have no depressant action on the respiration and circulation" (Kay, 1972, p123). This powerful quick acting drug is valuable to control convulsions in the maxillo-facial casualty suffering from a head injury.

Valium and Nitrazepam have a slight depressant effect on respiration but provided they are administered within the recommended therapeutic range and not in combination with an opiate, they are quite safe.

Vomiting during the immediate post-operative phase when the jaw is immobilised, is minimised by the strict adherence to the pre-operative-anaesthetic instructions. If vomiting does occur in a fasted patient it is usually free of solids and is therefore of almost liquid consistency. The vomitus can escape via the retromolar
spaces and through the feeding hole if present. If vomiting occurs in the conscious or semiconscious patient, the airway can be adequately protected by correct posturing and suction. Rarely does the intermaxillary fixation require releasing.

Kay (1972, p216) recommends the following anti-emetics for the control of post-operative vomiting:

<table>
<thead>
<tr>
<th>Name</th>
<th>Official Name</th>
<th>Dose</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stemetil</td>
<td>Prochlorperazine</td>
<td>5-12 mg.</td>
<td>Phenothiazine side effects avoid repeated use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.m.</td>
<td></td>
</tr>
<tr>
<td>Phenergan</td>
<td>Promethazine</td>
<td>25-50 mg.</td>
<td>Phenothiazine Antihistamine Sedative avoid repeated use.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.m.</td>
<td></td>
</tr>
<tr>
<td>Valium</td>
<td>Diazepam</td>
<td>5-10 mg.</td>
<td>Post-operative sedation, amnesia pronounced anti-emetic action (not as marked as Stemetil, Phenergan).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.v. or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>i.m.</td>
<td></td>
</tr>
</tbody>
</table>
2. **Infection**

Unless infection is already present it usually does not develop until a few days post-operatively. Careful regular observation of the temperature chart, the general physical appearance of the patient and the soft tissues overlying the fracture will assist in establishing a diagnosis of post-operative infection.

During the post-operative period there is usually some slight elevation of the temperature up to 100 degrees Fahrenheit (37.8°C). This is sometimes referred to as the 'aseptic traumatic fever' attributed to the absorption of proteins from effused blood at the fracture site. This moderate elevation in temperature should not extend beyond forty-eight hours and if this does occur or in the event there is a sudden rise in temperature during this period it is probably due to respiratory or oral infection.

a) **Respiratory Infection**

The most common cause of respiratory infection is the accumulation of blood or mucus in the bronchus or bronchioles preventing the free passage of air, leading to absorption collapse of the lung tissue distal to the point of impaction (Rowe and Killey, 1968, p591). The risk of inhalation of blood, mucus, teeth or denture fragments is greatest if the patient is rendered unconscious at the time of injury. Unwanted material
within the lung may result in the formation of a lung abscess.

The clinical signs of lower respiratory tract infection are:

- Rapid elevation of temperature over a six to eight hour period \(100-105^\circ F\) or \(37.8-40.6^\circ C\).
- Restlessness
- Rapid pulse
- Cyanosis
- Rapid respiration
- Diminished chest movement
- Dullness to percussion
- Broncho-pneumonia like symptoms

Should infection become established consultation with a physician is advisable. Treatment will generally be along the following lines:

- Postural drainage
- Antibiotics or chemotherapy
- Physiotherapy
- Tracheo-bronchial toilet
- Expectorants
- Tracheostomy in severe cases so as to establish adequate bronchial suction.

b) Oral Infection

"Since most fractures are compound, infection may develop because of contact with oral secretions and outside
air" (Archer, 1966, p895). Infection of the fracture haematoma to a minor extent is inevitable when the fracture is in communication with the oral cavity (Rowe and Killey, 1968, p180).

The absence of normal functional activity of the tongue combined with the difficulty in swallowing encourages stasis, accumulation of debris, and proliferation of micro-organisms with the increased risk of infection. It is therefore important, when and wherever possible, that oral hygiene is attended to as part of the pre-operative care, and maintained meticulously during the post-operative phase.

Comminuted fractures of the mandible, in particular gun shot injury, is characterised by a greater degree of hard and soft tissue disjunction. This type of fracture is likely to become infected. Kelsey Fry and Ward (1956, p306) in referring to compound comminuted fractures of the mandible state that this fracture is "almost invariably infected". Archer (1966, p895) concurs and says "In extensive comminuted fractures some bone is usually lost because of infection". He recommends leaving bone fragments until it is definitely proved that they are non-vital (free floating fragments in pus). Each fragment in a comminuted fracture is a potential source of osteogenesis provided infection is overcome. It is therefore imperative that no fragment is removed needlessly.
Early treatment within a few hours will minimise the risk of infection developing within the wound. Of course definitive treatment of the fracture is not always possible within the first day owing to the presence of other injuries. Under these circumstances great reliance is placed on antibiotic prophylaxis, in particular penicillin.

Clinical signs of oral infection - "An elevation of temperature from the development of infection within the oral cavity may occur at any time, but does not usually occur before the third or fifth day unless treatment has been delayed, and gross infection is present prior to operative interference" (Rowe and Killey, 1968, p591). Swelling that persists beyond the fourteenth post-operative day should be regarded with suspicion as it may indicate continued infection or gross displacement of the fracture fragments. In this event a thorough clinical and radiographic investigation is necessary.

A patient presenting with an acute infection looks ill and may have either a flushed, dry and hot skin or a pale cold and clammy appearance. The first type of patient usually has an elevated temperature, pulse and respiration rate. In the second type the temperature may be normal, or even subnormal and the patient's eyes appear dull. This patient is exhibiting poor resistance to infection and is referred to by Howe (1966, p159) as
'toxic'. Even in the absence of a febrile reaction antibiotic therapy should be commenced immediately to avoid further deterioration in the patient's condition.

**Osteomyelitis** - Suppurative osteomyelitis may arise as a complication of compound comminuted fracture of the mandible, especially if bones are inadequately immobilised as movement pumps micro-organisms directly into marrow spaces. Acute suppurative osteomyelitis is characterised by the presence of considerable pain, swelling, elevated temperature, trismus, regional lymphadenopathy and paraesthesia. In the fracture patient paraesthesia and trismus are signs of limited value. In the chronic state all these signs are present but in diminished intensity.

The course of this disease (and any other oro-facial infection) is primarily influenced by:
1. Virulence of the infecting organism
2. The adequacy of blood supply
3. Host resistance
4. Vigorous antibiotic therapy
5. Adequacy of fracture fixation (Rest of the part).

In ninety percent of cases the causative organism is either Staphylococcus aureus or Staphylococcus albus. The remainder of cases of suppurative osteomyelitis are infected by a mixture of organisms, primarily haemolytic streptococci, with Escherichia coli,
Pseudomonas, bacteroids and other oral contaminants (Limongelli et al., 1974). Osbon (1973) says "Osteomyelitis is usually a mixed infection with staphylococcus aureus being the most common organism".... "In addition it is necessary to rule out the anaerobic organisms".

Leake in 1972 reported a rare case of bacteroides osteomyelitis complicating a compound comminuted fracture of the mandible and treated successfully with clindamycin. The author has treated one case of bacteroides osteomyelitis following a compound mandibular fracture. From culture and sensitivity tests the recommended antibiotic was lincomycin. Successful treatment consisted of establishing effective immobilisation of the lower jaw; incision and drainage of pus; placement of a corrugated drain for forty-eight hours and vigourous antimicrobial therapy with lincomycin i.m.

Leake maintains that clindamycin is the drug of choice because its spectrum includes both anaerobic and aerobic streptococci and actinomycyes and bacteroids as well. Ball et al. 1975 state: "It appears from in vitro comparison that clindamycin is more effective than the parent compound, lincomycin, and as active as erythromycin or more so against Gram-positive streptococci and erythromycin sensitive Staphylococcus aureus, as well as penicillinase-producing organisms and Actinomycyes".
The relatively poor collateral blood supply to the mandible compared to the maxilla helps explain the higher incidence of osteomyelitis involving the lower jaw. Furthermore, reduced host resistance in conditions such as leukaemia, anaemia, blood dyscrasias, poorly controlled diabetes and any chronic debilitating illness renders the patient more vulnerable to contracting osteomyelitis and more difficult to treat effectively. Fontanesi (1974) places the major emphasis on inadequate fracture fixation. He believes, too often the blame is placed on other factors such as debility, age, etc., when in fact inadequate fixation of the fracture is the likely cause.

The frequency of bone infection among chronic alcoholics is not generally appreciated. However, it has become apparent from the work of Silberman et al 1974 that the incidence of osteomyelitis although rare in the general population increases significantly in chronic alcoholism. They concluded that an alcoholic with a compound mandibular fracture is more prone to develop bone infection. Apparently fat emboli from the alcoholic 'fatty liver' enter circulation from time to time and lodge in small vessels within the mandible thereby decreasing an already limited blood supply by causing thrombosis within these vessels which may lead to 'microinfarction' within the bone.
In Silberman's series of 636 mandibular fractures, the incidence of osteomyelitis was 3.4 percent, however, all twenty cases of osteomyelitis were chronic alcoholics. Certainly, those patients with a history of alcoholism will be prone to infection following any bone surgery, therefore, antibiotic prophylaxis is justified.

Treatment for Osteomyelitis - Treatment should be along conservative lines and "In many cases, adequate immobilisation with eradication of the disease process alone may result in complete bony union, thus obviating the need for subsequent bone graft" (Limonelli et al. 1974).

The complication of osteomyelitis following a compound comminuted fracture of the mandible may require surgical treatment but antibiotics play an important part in the resolution of this condition. Kay (1968, p689) recommends commencing treatment with Benzylpenicillin 500,000 units four hourly and continued for three weeks. If there is little or no response within forty-eight hours of commencing treatment a tetracycline (250 mg. six hourly) is recommended. Kay claims there is mounting evidence of the effectiveness of lincomycin 500 mg. six hourly by mouth in staphylococcal osteomyelitis. Tolhurst et al (1972, pl85) maintains that lincomycin has been used with good effect in both staphylococcal and streptococcal infections, and say "It is the most
suitable alternative to the penicillins and competes with them for precedence". The dosage recommended is 600 mg. intra-muscularly statim, followed by 500 mg. eight hourly by mouth, for adults. However, one must keep in mind when administering this drug that diarrhoea, nausea, abdominal cramps and skin rashes are possible side effects.

Sachs (1974) favours aqueous penicillin as a first choice. He recommends very large initial doses e.g., two million units given i.m., every four hours. However, as an alternative drug when penicillin is ineffective he suggests lincomycin 500 mg. given orally every six hours.

Leake (1972) selects penicillin as first choice. He recommends ten million units i.v. over a twenty-four hour period, but selects clindamycin when the clinical response to penicillin is unfavourable. He suggests a total of 1,200 mg. of clindamycin given daily in divided doses.

There are some cases of osteomyelitis in which the very early administration of antibiotics in large doses will abort the infection and the need for surgical intervention. However, as a general rule surgical intervention is necessary, although it may be less extensive.

Actinomycosis - Although very rare, actinomycosis must be kept in mind as a possible complication of mandibular
fracture. When on clinical grounds this disease is suspected it is essential that any specimen sent for bacteriological examination is accompanied by a special instruction requesting laboratory confirmation of actinomycosis.

The ideal specimen should be more than a swab stick coated in pus. Several millilitres of pus are required and the first few drops included as this portion often contains the highest concentration of the organism. The presence of sulphur granules in pus does not necessarily establish a diagnosis of actinomycosis as the organism is a normal inhabitant of the oral cavity and frequently present in mixed infections. Final diagnosis must be based upon clinical, bacteriological and pathological evidence.

Cervico-facial actinomycosis can be treated successfully with one of a number of antibiotics effective against this Gram positive anaerobe, provided adequate blood concentrations are maintained for a month or two after the signs of the disease have subsided. Kay (1972, p87) states that "with classical actinomycosis the treatment span is at least six weeks". Continuing therapy beyond the immediate clinical resolution of the disease minimises the risk of recurrence.

Penicillin is the drug of choice and is given as fortified procaine penicillin 1.2 million units daily i.m.
2. **Prevention of Oral Infection**

The prevention of oral infection can be divided into local and systemic measures.

a) **Local Measures** - The fractured jaw patient rapidly develops a foul dirty mouth in the absence of meticulous oral hygiene. This is particularly so for cases of gunshot injury to the mandible.

In 'civilian' type mandibular fractures it is uncommon to find gross laceration and loss of soft tissues of the mouth. Healing of the mucosa is usually rapid and without complication. Gunshot injury to the mandible on the other hand exhibits gross wounding and the increased risk of gross hard and soft tissue infection. Therefore, attention to oral hygiene is of greatest importance in this type of injury.

It is essential that the nursing staff and the patient are aware of the importance of meticulous oral hygiene. This involves careful irrigation of the mouth following each meal, followed by tooth brushing to remove any residual food debris or mucinous plaque from the splints, wires and exposed teeth.

"The action of any solution employed is principally mechanical; however, the inclusion of sodium bicarbonate is of considerable assistance in dissolving the mucus film, and is therefore employed for irrigation purposes. Some glycerine of thymol is usually added to improve the
flavour" (Rowe and Killey, 1968, p592). If halitosis is marked, or investigation confirms the presence of coliform organisms, Rowe and Killey recommend Eusol one percent or sodium perborate.

The use of an antiseptic mouthwash is only secondary to the mechanical effects of irrigation and tooth brushing. Kay (1972, p247) states "The antibacterial action must, however, be transient, for the fluid is retained in the mouth for only a few minutes at a time and concentration falls rapidly as a result of progressive dilution by salivary flow". He goes on to say there is nothing superior to hot saline used two hourly for the removal of organic debris and the production of tissue hyperaemia. A hypertonic solution such as this would also tend to withdraw water from bacterial cells thereby suppressing their vitality.

The use of chlorhexidine as a mouthwash (0.2% solution) is a popular means to inhibit plaque formation in all areas of the dentition. This may be of some benefit in reducing dental caries and gingivitis however, its therapeutic value in the prevention and control of oral infection is questionable. This view is supported by Kay (1972, p200).

A new technical innovation which is of considerable benefit in maintaining good oral hygiene is the 'water-pick'. The pulsating jet of water is helpful in maintaining
debris free interproximal spaces and for removing food material adherent to wires and splints but must not be used in the region of the fracture as organisms and food debris may be driven deep into the wound.

b) **Systemic Measures**

The administration of prophylactic antibiotics in the presence of traumatic injury is controversial. Paterson et al. (1970) after reviewing the literature and conducting his own survey concluded that the value of prophylactic antibiotic cover in patients who require elective surgery or had suffered traumatic injury is questionable in preventing local infection.

They found that patients treated prophylactically with antibiotics had an overall post-operative infection rate of 15.38 percent. The infection rate of patients not receiving prophylactic antibiotics was 9.9 percent.

Paterson and co-workers 1970, concluded:

1. Prophylactic antibiotics are associated with a higher rate of infection, a higher degree of antibiotic resistant infections and a higher degree of superimposed infections.

2. Prophylactic antibiotics may complicate the scientific management of subsequent infections.

3. The high degree of success in modern oral surgery and the decreasing incidence of osteomyelitis is
due to improvements in surgical techniques and the availability of antibiotics rather than prophylaxis per se.

On the theme of 'prophylaxis' Osbon (1973, p423) states "After studying the prophylactic use of antibiotics in over one thousand cases of general surgery, Johnstone observed that prophylactic antibiotics not only failed to prevent, but also were in fact associated with an increase in infections of all types".

It is the author's belief that the administration of an antibiotic prior to an 'elective' oral surgical procedure, is in the majority of cases unwarranted. It presupposes, quite falsely, two conditions:

1. Infection is likely to develop in the wound post-operatively.
2. The causative organisms are sensitive to the antibiotic chosen empirically.

However, it is also my belief that the administration of a suitable antibiotic is justified in the presence of a compound comminuted fracture of the mandible. Zallen and Curry (1975) convincingly demonstrated the need for prophylactic antibiotics in the presence of any compound mandibular fracture. Problems related to infection at the fracture site developed in only 6.5 percent of patients treated with antibiotics. In contrast, infections developed in 50.33 percent of patients not receiving prophylactic antibiotics.
The criticism of the free use of prophylactic antibiotics has been based on the following grounds:

1. Hypersensitivity
2. Resistance
3. Minimises the reliability of subsequent culture and sensitivity tests

On the prophylactic administration of antibiotics, Garrod, Lambert and O'Grady (1973, p286) state "studies have usually shown a higher infection rate in treated than control patients. The principle involved here is that treatment does nothing to remove the predisposing cause; if this is strongly operative infection will always follow, and all that the antibiotic does is to select a resistant pathogen".

However, they do say that prophylactic antibiotic protection is justified in extensive trauma with gross soiling of the wound and a general policy on prophylaxis should be to restrict it to the few patients clearly requiring it as there is abundant evidence that the lavish use of antibiotics favours the spread of resistant species.

3. Damage to Nerves and Blood Vessels
   a) Nerve Damage

   Damage to the inferior dental nerve as a result of a fractured mandible usually produces anaesthesia on the affected side over the distribution of the mental branch. Depending on the severity of nerve damage
anaesthesia of the skin may persist from a few days to many months and in some cases is permanent. When the nerve has only been crushed or bruised sensation will return in anything from a week or so to two or three months (Kelsey Fry and Ward, 1956, p327). If the nerve is severed Wallerian degeneration occurs in the distal portion and recovery by regeneration from the proximal portion takes between three to twelve months, which is preceded by 'tingling', paraesthesia and hyperaesthesia of the tissues (Rowe and Killey, 1968, p13). The rate of recovery will depend upon:

1. Accuracy of approximation of the nerve ends which is directly related to the accuracy of fracture reduction.
2. The elimination of infection.
3. Rigid fixation preventing undue mobility.
4. Absence of any intervening hard or soft tissue within the mandibular canal.

Archer (1966, p895) makes the following statement "Normal sensation will usually return to the lip in time, except in cases of comminuted fractures". This statement although not true for every case of comminuted fracture is applicable to moderate and severely comminuted mandibles. The probability for return to normal sensation in this type of injury is understandably
low when one considers the local severity of the trauma and that comminuted fractures are more difficult to accurately approximate, more difficult to rigidly fix, more likely to exhibit varying degrees of bone loss and more prone to develop gross infection when compared to simple mandibular fractures. In the presence of prolonged suppuration, which was commonly the case during the pre-antibiotic era, sensation will rarely return to the lip.

During the healing phase of the inferior dental nerve, pain is sometimes referred to the ear. Before sending a fracture patient for medical consultation one should explain that the ear ache is likely to be referred pain from the healing fracture.

b) Vascular Damage

Secondary haemorrhage from erosion of a blood vessel by infection is most likely to occur in a gunshot wound between seven to fourteen days after trauma. Every effort must be made to control infection both locally and systemically. "The essence of treatment of secondary haemorrhage is forethought and promptitude, for the emergency is sudden and if treatment is delayed it may be too late" (Kelsey Fry and Ward, 1956, p107). The incidence of secondary haemorrhage in severe gunshot types of injury is high enough to be serious especially
where facilities are limited eg. in a war zone.

There have been a few reports of false aneurysm of the facial artery following circumferential wiring of a mandibular fracture (Van den Akker and Van der Linj 1974, Rowe and Killey, 1968, p191). Care must be taken to avoid ligating the mandible at the point where the facial artery crosses the lower border. Classically the aneurysmal swelling develops some days after operation and presents as a pulsating mass. Treatment involves exposure, ligation and sectioning of the facial vessel. A false aneurysm is not life threatening unless the aneurysm bursts. However, immediate unexpected haemorrhage may be life threatening.

Rowe and Killey (1968, p191) report such a case - "a circumferential wire was passed around the mandible in the left canine region in the normal manner but, within thirty seconds it was observed that the tissues in the floor of the mouth were commencing to rise at an alarming rate. The tongue became markedly elevated and attempts to control what was obviously a deep haemorrhage by pressure had little effect. Within two minutes the appearance of the floor of the mouth resembled that seen in Ludwig's angina". Fortunately the bleeding did not track any further along the fascial planes. However, if blood proceeded to track a tracheostomy would have been indicated.
In order to minimise the risk of violating an artery the tip of the bone awl should be kept in close contact with periosteum when ligating the mandible with wire.

4. **Limitation of Mandibular Movement**

There are several factors that minimise jaw movements following fracture treatment:

1. Inflammation of soft tissue
2. Myositis ossificans
3. Foreign body
4. Malunion
5. Joint injuries
6. Coronoid and Zygomatic Arch injuries
7. Scar tissue
8. 'Neurotic' limitations of movement

- **Inflammation of soft tissues** - inability to open the jaw will be partly due to swelling and partly due to pain. Treatment consists of identifying the cause, regular application of heat intra-orally and/or extra-orally, to be followed by jaw exercise.

- **Myositis ossificans** - this is a rare complication following trauma to muscle. New bone may appear radiographically to be invading muscle, and it may in fact be laid down between bundles of muscle fibres. The latter do not, however, become ossified and the commonly used term 'myositis ossificans' is a
misnomer (Wiles and Sweetnam, 1965, p358). Crawford Adams (1967, p104) states "The bone is formed by metaplasia of connective tissue cells, not from displaced osteoblasts".

Rowe and Killey (1968, p194) report a case and claim that it is the result of organisation and subsequent ossification of an intra-masseteric haematoma. Treatment consists of surgical removal of the ossified mass followed by gradual jaw exercise.

**Foreign body** - Implantation of a foreign body may elude detection. This is often a source of chronic indolent infection which may be characterised by the presence of a persistantly discharging sinus. Treatment involves surgical exploration and removal of the foreign material.

Blast injuries, bullet wounds and high speed traffic injuries are likely to be associated with implantation of foreign material deep within soft tissue. Radiographic examination of soft tissue using 'soft penetration' for low contrast is useful when suspecting the presence of a foreign body. A metal detector can be useful in locating metal objects deep in tissue, but it may be unwise to attempt to remove a foreign body that is close to a major structure.

**Malunion** - refer section 5.
Joint injuries - following injuries to the temporomandibular joint, bony or fibrous ankylosis may occur, resulting in limitation of jaw movement varying from slight loss of function to complete fixation. Comminution of the condylar head is especially susceptible to this complication as haemorrhage into the joint cavity can organise and even calcify.

Bony ankylosis of the jaw joint will require condylectomy, followed by treatment as for fracture dislocation of the condyle. Fibrous ankylosis may be less serious and can in most cases be treated by functional methods.

Coronoid and zygomatic arch injuries - There is a remote danger of fibrous or bony union occurring between the coronoid process and either the lateral aspect of the maxilla or the zygomatic arch. This is particularly relevant in comminuted fractures of the vertical ramus and fractures of the zygomatic arch and should be watched for or anticipated during the early treatment phase.

Scar tissue - gross limitation of jaw movements can be seen following facial burns. As a rule, extreme limitation due to scarring does not follow mandibular fracture, except in cases of severe gunshot comminution of the mandible associated with hard and soft tissue avulsion. The presence of prolonged infection, delayed
treatment and poor treatment increases the probability of scar formation and limitation to jaw movement.

'Neurotic' limitation of movement - Through fear or a desire for attention, some patients subconsciously limit jaw movements. Other patients, fortunately few, are conscious malingerers. A test that differentiates genuine patients from the 'neurotic' disturbed patient and the conscious malingerer has been described by Kelsey Fry and Ward (1956, p319), "the patient is given a hand mirror so that he can observe the opening of the mandible when the pharynx is stimulated. The conscious malingerer will realise that he has been found out and will give no further trouble. The subconscious malingerer cannot open his mandible because he does not believe that it is possible; when he is shown that it is possible, his disbelief is overcome".

5. Delayed Union, Malunion, Nonunion
   a) Delayed union

Most uninfected fractures heal within two to eight weeks depending upon the severity of the fracture, age and health. Compound comminuted fractures of the mandible are more likely to become infected and suppurative when compared to 'simple' mandibular fractures, and under these conditions, the comminuted fracture will generally take longer than eight weeks to unite.
If there is an area of bone loss prolonged immobilisation may obviate the need for a bone graft by allowing additional time for bone to 'naturally' bridge the gap.

It becomes obvious that the term delayed union is relative, for there is no apparently normal time in which fractures should unite.

b) **Malunion**

Malunion is often a sequela of no treatment or inadequate treatment. The degree of handicap is related to the function and appearance.

In some cases the disturbance can be accommodated by the extraction of one or two selected teeth; the construction of new dentures and natural remodelling of the mandible. However, if the disturbance to function and aesthetics is marked the mandible will need to be refractured and set in the true anatomical position.

c) **Nonunion**

In this condition fracture ends fail to unite. Frequently this complication is the result of poor treatment. Common causes of nonunion are:

1. Inadequate fracture fixation (excessive mobility)
2. Delayed treatment
3. Removal of appliances too soon (inadequate period of immobilisation or fixation)
4. Interposition of soft tissues (particularly relevant to comminuted fractures)

5. Failure to establish drainage in the presence of pus

6. General debilitating disease (poor healing)

The degree of handicap is related to the site of nonunion and the density of fibrous tissues across the fracture site. Fibrous union following fracture dislocation of the condyle does not require correction. Likewise, fibrous union of a fracture involving the vertical ramus seldom if ever presents a functional problem. However, the disability is magnified the closer the fracture is to the mid-line. Nonunion forwards of the angle, in some cases, will require a bone graft. However, minor degrees of bone loss can be handled by freshening up the bone ends and directly fixing the fragments. Radiographically eburnation of the bone ends is pathognomonic of nonunion.
The Prevention and Treatment of Post-operative Complications

- References


STATISTICS ON AETIOLOGY AND INCIDENCE OF MANDIBULAR
FRACTURES AND CURRENT TRENDS IN FRACTURE MANAGEMENT

A comminuted fracture of the mandible is usually
the result of extreme violence. In a civilian community
the incidence of this type of fracture is very low in
comparison to other types of fracture involving the
lower jaw (Table 1).

1. The Incidence of Comminuted Fractures of The Mandible

The frequency with which comminuted fractures of the
mandible occur can be related to three distinct groups:

1. Military Combatants - those engaged in active
   military combat.

2. Non Combat Military Personnel - those currently
   in non combat situations.

3. Civilians.

Alling (1974) reported that in Vietnam 75.4% of all
mandibular fractures sustained by combat troops were
comminuted. In non combat military situations the
incidence of comminuted fracture was 18.5%, however, in
civilian life this type of fracture is less frequent and
according to Rowe and Killey (1968, p872) represent only
2.6% of all mandibular fractures.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Series A</th>
<th>Series B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>382 Cases</td>
<td>617 Cases</td>
</tr>
<tr>
<td>Single fracture</td>
<td>43.7%</td>
<td>67.74</td>
</tr>
<tr>
<td>Double</td>
<td>41.1%</td>
<td>22.67</td>
</tr>
<tr>
<td>Triple</td>
<td>13.3%</td>
<td>5.83</td>
</tr>
<tr>
<td>Quadruple</td>
<td>0.3%</td>
<td>0.48</td>
</tr>
<tr>
<td>Comminuted</td>
<td>1.6%</td>
<td>3.22</td>
</tr>
</tbody>
</table>

\[ \text{mean } \% = 58.55 \]
\[ \text{mean } \% = 29.74 \]
\[ \text{mean } \% = 8.7 \]
\[ \text{mean } \% = 0.4 \]
\[ \text{mean } \% = 2.6 \]
2. The Aetiology of Mandibular Fractures and Comminuted Fractures

In civilian life comminuted fracture of the mandible may be produced by a variety of causes for example, assault and battery, high speed transportation accidents, industrial injuries, projectiles from fire arms and invasion of the tissues by other high velocity objects. Classically, this type of fracture is produced by a penetrating object. A rare injury but one that usually produces extensive comminution of the facial bones is that of accidental tyre-rim explosion (Bautista, 1971).

In Britain Rowe and Killey (1968, p860) found in their study that 46.8% of fractures of the facial skeleton were due to road traffic accidents, however, after analysis of Table XIV p868 in their book it is clear that road traffic accidents account for only 34.31% of all mandibular fractures.

A French study undertaken by Achard and Freidal (1970) examined 2000 cases of mandibular fracture over an eighteen year period, and concluded that road accidents were the major aetiologic factor (64.0%). Although road traffic accidents are the predominant aetiologic factor in producing mandibular fractures, the type of fracture produced is rarely comminuted. However, by way of comparison injuries to the middle-third of the face are mostly comminuted.
### TABLE II

**The Aetiology of Mandibular Fractures (France) - Achard and Freidal 1970**

**Road Accidents:**
- 1950-1960 predominantly from two wheel vehicles: 64.0%

**Industrial Accidents:**
- Slowly on the decline: 19.0%

**Sports:**
- Horseback riding, skiing, football: 8.0%
- Soccer, etc.: 5.0%

**Altercations:**
- 5.0%

**Miscellaneous:**
- Firearms, pathology: 4.0%

**100.0%**

Statistics will vary according to the geographic, social and economic circumstances in the community sampled.

3. **The Incidence of Comminuted Mandibular Fractures in Relation to Maxillofacial Fractures**

According to Achard and Freidal (1970) mandibular fractures account for 56.0% of all maxillofacial fractures in their series of 3,514 cases. Rowe and Killey (1968) in a series of 1,500 maxillofacial fractures report 871 as mandibular and 501 as middle third fractures. Expressed as a percentage, mandibular fractures represent 58.0% of all maxillofacial fractures.
Using the incidence of 'civilian' comminuted mandibular fractures as being 2.6% of all lower jaw fractures, one can calculate the incidence of this type of fracture as being very low in relation to all maxillofacial fractures (3 per 200 maxillofacial injuries in civilian life).

Maxillary fractures represent 33% of all maxillofacial injuries, and the combined injury of maxilla and mandible represents 9% of maxillofacial injuries. (The author has calculated these percentages from the appendix of Rowe and Killey, 1968).

4. The Location and Frequency of Mandibular Fractures

Taking the study of Achard and Freidal as an example, the sub-condylar fracture is the most common. It represents 14.8% of all maxillofacial fractures and 26.36% of mandibular fractures. Fractures of the malar and zygomatic arch were found by way of comparison to be almost as common as the sub-condylar fracture and represented 14% of all facial fractures observed in their series. (These comments arise from the author's interpretation of statistics presented by Achard and Freidal, 1970).
TABLE III - (Achard and Freidal)

Various Locations of Fractures of The Mandible:

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveolar process</td>
<td>8.67%</td>
</tr>
<tr>
<td>Symphysis</td>
<td>6.64%</td>
</tr>
<tr>
<td>Parasympysis</td>
<td>22.36%</td>
</tr>
<tr>
<td>Lateral</td>
<td>11.76%</td>
</tr>
<tr>
<td>Angle</td>
<td>18.0%</td>
</tr>
<tr>
<td>Ramus</td>
<td>4.00%</td>
</tr>
<tr>
<td>Coronoid process</td>
<td>1.60%</td>
</tr>
<tr>
<td>Condyle</td>
<td>26.36%</td>
</tr>
</tbody>
</table>

Total Cases 1,972

The term parasympysis refers to the first premolar region. The term lateral refers to the portion of the body between the angle and the parasympysis.

5. The Distribution of Mandibular Fractures in Adults and Children

According to Achard and Freidal (1970) the distribution of lower jaw fractures is:

- Adult males - 76%
- Adult females - 16%
- Children under 12 years - 8%

It is obvious that a mandibular fracture occurs about five times as often in men as in women and about nine times as often in men as in children. Women
sustain a fractured mandible twice as frequently as do children.

6. **Trends in Management of Comminuted Fractures of the Mandible**

Marlette (1970) in a paper presented to the "Third International Conference on Oral Surgery", inferred that the trends in fracture management as conducted by military oral surgeons were representative of the trends in fracture management as practised by civilian oral surgeons throughout the United States. He further claims that the modes of treatment as presented in his survey were indicative of a cross-section of commonly accepted methods of fracture management throughout the United States.

Certainly, taking Alling's figure of 18.5% as being representative of the incidence of mandibular comminuted fractures in the non-combat military situation, one can infer that a significant number of fractures treated by Marlette were comminuted.

He conducted his survey among qualified oral surgeons in the European Theatre of Operations (NATO) using the unsigned questionnaire technique. Questionnaires were designed to evaluate the preferences between several basic methods of treatment. The following table lists the accepted methods of treatment of mandibular fractures if a choice is available.
TABLE IV

<table>
<thead>
<tr>
<th>Type</th>
<th>Mandibular</th>
<th>Accepted by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone plate</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Osseous wire</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Kirschner wire</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>External pins</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Acrylic splints</td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td>Metal splints</td>
<td></td>
<td>70%</td>
</tr>
<tr>
<td>Wire fixation</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Elastic traction</td>
<td></td>
<td>90%</td>
</tr>
</tbody>
</table>

The results of this study can be summarised as follows:

- All surgeons preferred to avoid the use of Kirschner wires and external pin fixation. Generally other techniques were used for definitive treatment.
- The majority of surgeons preferred an extra-oral open reduction technique and direct bone wiring. The goal of anatomical realignment was considered best achieved by open reduction and fixation under direct vision.
- Intra-oral open reduction was used for those cases exhibiting minimal displacement.
- Stainless steel was still the material of choice for direct bone wiring.
- Bone plates were occasionally used in bone grafting
procedures or non-unions.

. Cast metal splints were preferred to acrylic splints and elastic traction for intermaxillary fixation was preferred to wire ligation.

Another group of questions designed to find out the operator's preferences for supportive treatment was included in Marlette's survey (refer Table V)

| TABLE V  |
| Supportive (Adjunctive) Treatment |
| Modality | Accepted by |
| Pressure dressing | 100% |
| Wound coverage | 0% |
| Anti-inflammatory drugs | 0% |
| Enzyme therapy | 0% |
| Penicillin | 100% |
| Other antibiotics | 0% |
| Pull-out wires | 60% |
| None | 40% |
| Suture removal - 3 days | 30% |
| Suture removal - 5 days | 50% |
| Suture removal - 7 days | 20% |
| Dermalon sutures | 80% |
| Other types of sutures | 20% |

Results

. Basic surgical principles were universally accepted, that is, administration of antibiotics specific for Gram
positive organisms, the use of pressure dressings, careful handling of soft tissues and the use of fine sutures for skin closure.

- Penicillin was the antibiotic of first choice when a history of previous hypersensitivity did not exist.
- Dermalon sutures were preferred to other types. The use of anti-inflammatory agents was not widely accepted and the time for the removal of sutures ranged from three to seven days. There was disagreement as to the need for removal of the transosseous wire.

Although not contained within the above table, the time lag between injury and operation for the treatment of mandibular fractures ranged from three hours to five days. Generally mandibular fractures, uncomplicated by fractures of the upper facial bones, were treated at about twelve hours after injury.

Crewe 1966 presented the following tables showing procedures used for the treatment of mandibular fractures at the Plymouth General Hospital, England during the period 1956-1965.
### TABLE VI

#### Treatment of Mandibular Fractures - I

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>NTR</th>
<th>Closed</th>
<th>Open</th>
<th>LBW</th>
<th>UBW</th>
<th>Plated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>39</td>
<td>4</td>
<td>33</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1957</td>
<td>44</td>
<td>3</td>
<td>39</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1958</td>
<td>34</td>
<td>5</td>
<td>28</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1959</td>
<td>40</td>
<td>7</td>
<td>26</td>
<td>7</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1960</td>
<td>66</td>
<td>15</td>
<td>41</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>1961</td>
<td>56</td>
<td>13</td>
<td>32</td>
<td>11</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>49</td>
<td>6</td>
<td>34</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1963</td>
<td>50</td>
<td>3</td>
<td>32</td>
<td>15</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>1964</td>
<td>55</td>
<td>7</td>
<td>30</td>
<td>18</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>1965</td>
<td>51</td>
<td>4</td>
<td>31</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Column 1 shows the year; column 2 the total number of mandibular fractures seen in that year; column 3 the number of these cases in which no treatment was required (NTR); column 4 the number treated by closed reduction; column 5 the number treated by open reduction. Columns 6, 7 and 8 show a breakdown of open reductions by method used (LBW, lower border wire; UBW, upper border wire; bone plate).
<table>
<thead>
<tr>
<th>Year</th>
<th>Treated</th>
<th>Closed</th>
<th>Open</th>
<th>LBW</th>
<th>UBW</th>
<th>Plated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>percent</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1956</td>
<td>35</td>
<td>94.3</td>
<td>5.7</td>
<td>5.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1957</td>
<td>41</td>
<td>95.1</td>
<td>4.9</td>
<td>4.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1958</td>
<td>29</td>
<td>96.6</td>
<td>3.4</td>
<td>3.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1959</td>
<td>33</td>
<td>78.8</td>
<td>21.0</td>
<td>21.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1960</td>
<td>51</td>
<td>80.4</td>
<td>19.6</td>
<td>9.8</td>
<td>9.8</td>
<td>-</td>
</tr>
<tr>
<td>1961</td>
<td>43</td>
<td>74.4</td>
<td>25.6</td>
<td>18.6</td>
<td>7.0</td>
<td>-</td>
</tr>
<tr>
<td>1962</td>
<td>43</td>
<td>79.1</td>
<td>20.9</td>
<td>9.3</td>
<td>4.6</td>
<td>7.0</td>
</tr>
<tr>
<td>1963</td>
<td>47</td>
<td>68.1</td>
<td>31.9</td>
<td>4.3</td>
<td>2.1</td>
<td>25.5</td>
</tr>
<tr>
<td>1964</td>
<td>48</td>
<td>62.5</td>
<td>37.5</td>
<td>10.4</td>
<td>8.3</td>
<td>18.8</td>
</tr>
<tr>
<td>1965</td>
<td>47</td>
<td>66.0</td>
<td>34.0</td>
<td>8.5</td>
<td>10.6</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Those cases in which no treatment was required are omitted from this table. Column I shows the year; column 2 the total number of mandibular fractures treated in that year; column 3 the percentage of these cases treated by closed reduction; and column 4 the percentage treated by open reduction. Columns 5, 6 and 7 show a breakdown of the open reductions by the method used, expressed as a percentage (LBW, lower border wire; UBW, upper border wire; bone plate).
These tables reflect the trend towards surgical rather than 'appliance methods'. There is an overall increase in open reduction techniques ie. lower and upper border wiring and bone plating. This trend to a surgical approach is probably due to the improved academic and surgical training available to 'apprentice' oral surgeons and the fact that no longer are oral surgeons and patients prepared to accept a degree of malunion, which is more likely to occur using indirect methods.

Crewe (1966) questions the necessity for and duration of intermaxillary fixation. Although immobilisation of the jaw is considered necessary in some cases, how necessary is this in view of the techniques available today? Direct bone wiring has an important bearing on the duration of or necessity for intermaxillary fixation. Various methods of fracture reduction and fixation that eliminate or reduce the period of intermaxillary fixation have been reported (Thoma, 1948, Reiter, 1948, Hahn and Corgill, 1969, Khedroo, 1970).

Curry and Zallen (1974) state "In recent years oral surgeons have become aware of several complicating situations necessitating reduction of mandibular fractures by some method whereby intermaxillary fixation time can be shortened or eliminated altogether". Patients suffering from epilepsy, alcoholism and various mental and neurological disorders should be offered some form of
internal fixation that assures adequate support with or without intermaxillary fixation. Curry and Zallen (1974) recommend the use of a Vitallium or Titanium mesh that is malleable. Its rigidity enables it to be used for those cases unsuited to prolonged intermaxillary fixation or when early mobilisation is required. The titanium mesh has three major advantages over other methods of osteosynthesis for a comminuted mandible.

1. Versatility
2. Stability
3. Patient acceptability

The mesh is versatile in that it is readily adapted to fractures occurring anywhere between the angle and symphysis. Minor adjustments are easily made and the numerous positions available for placing screws facilitates spanning of a comminuted or avulsed segment of the mandible. Numerous successes have been reported in the literature with the use of metallic mesh of varying types (Gargiulo et al. 1973, Worley et al. 1973, Bear et al. 1971) and more recently the use of non-metallic mesh has been reported by Leake (1974). Five of the nine cases treated by Curry and Zallen (1974) did not require immobilisation and there were no complications reported. However, if infection did develop about the metallic mesh its removal would be a very tedious and difficult surgical procedure.
Fig. 36 - The pericortical bone clamp as used by Kline, 1973.
Kline (1973) describes the use of a peri-cortical clamp for rigid fixation using the lateral compression principle (Fig. 36). Utilizing a clamp system supplemental immobilisation was eliminated in edentulous patients and the length of time that was necessary for immobilisation of the fractured jaws in dentulous patients was significantly reduced (not more than three weeks).

However, there are two obvious disadvantages of the lateral compression clamp as described by Kline:

1. In atrophic edentulous mandibles the clamp impinges on the denture bearing area and may need to be removed.

2. Because of bulk, it can only be used to span a small comminuted area.

Brons and Boering (1970) describe three means of obtaining absolute rigidity at the fracture site and thereby reducing the period of supplemental immobilisation. In fact they treated forty cases of mandibular fractures in which intermaxillary fixation was omitted.

The three methods they suggest are bone plating, screws and a new method of direct bone wiring (Fig. 37, 38).

The technique of direct wiring is performed by placing two drill holes above the mandibular canal and close to the fracture line. The second holes are drilled beneath the canal. Wire is passed through the upper pair of drill holes twisted very tightly and taken inferiorly
Fig. 37 - The new technique for direct wiring of mandibular fractures as proposed by Brons and Boering, 1970.
Fig. 38 - Brons and Boering's technique applied to treat a minor comminuted fracture.
to form a sling by introducing the ends through the lingual side of the lower holes.

Juniper and Awty (1973) analysed 270 cases of fracture of the body of the mandible treated at East Grinstead, England. Their policy of removing intermaxillary fixation at three weeks seems vindicated. Only 2.7 percent of fractures required immobilisation for longer than six weeks.

Crewe (1966) presented a rational approach to the management of mandibular fractures. Since the displacing forces are mainly muscular, rigid interosseous fixation as supplied by a bone plate or vitallium mesh and to some degree by direct bone wiring, can resist these forces and thereby reduce the need for prolonged intermaxillary fixation. A symphyseal fracture held securely by stainless steel wires at the lower border need be immobilised for one to two weeks only, and edentulous patients do not require immobilisation.

In cases of fracture at the angle or the body of the mandible the displacing forces tend to open the fracture at the upper border. A lower border wire will not prevent this, therefore contributing very little to reducing the time necessary for intermaxillary fixation. Likewise, an upper border wire will not appreciably reduce immobilisation time as it will slowly cut through the soft alveolar bone. Crewe suggests that bone plating across the lower border
will provide the rigidity and resistance to displacement that is necessary to dispense with intermaxillary fixation.

The fractures he illustrated were not comminuted fractures but the principles can be applied in treating the comminuted mandible.

The rather short immobilisation times recommended by Crewe (1966), Brons and Boering (1970), Juniper and Awty (1973) cannot be universally recommended for comminuted fractures of the mandible. It is true that some comminuted fractures need not be immobilised provided rigid fixation is established at the area of fracture. Brons and Boering (1970) presented a case of minor comminution successfully fixed with stainless steel wire without immobilisation of the mandible. However, moderate to extensive comminuted fractures of the lower jaw will generally require intermaxillary fixation, but in view of current trends, the period of immobilisation in the past may have been somewhat excessive. There is nothing to be lost by being cautious but the convenience and comfort of the patient must be considered.

7. A New Type of Fixation Appliance

Biodegradable fixation appliances (polylactic acid) have been described and point to future methods of internal fixation (Götter et al. 1972). One would hope that a biodegradable mesh could be developed with sufficient
strength and rigidity to span a comminuted fracture area. Under these circumstances the comminuted fragments could be cradled by the fixation appliance.

If the appliance were of sufficient strength and rigidity intermaxillary fixation would not be required in many cases. The experiment on mandibles (dogs) indicate that by twenty-four weeks post-operatively the biodegradable fixation plates used by Getter et al. could not be seen or palpated.

8. The Tooth in The Line of Fracture

The concept of a tooth in a fracture line must be revised when thinking of comminuted fractures of the mandible. Comminuted fractures are more complex than the single type fracture and most often there are teeth and fragments haphazardly arranged. It would be more correct to consider a tooth in a fracture fragment or island of bone rather than in association with a fracture line. On this Kelsey Fry and Ward (1956, p97) say "Comminuted fragments may contain teeth whose immediate extraction would involve the loss of valuable bone. A policy of temporization for a week or so may well be adopted".

Calhoun and Perkins (1958) state "With proper and adequate antibiotic therapy to control infection, teeth in or near the line of fracture may be used to secure adequate immobilisation of the fractures of the mandible. Schneider et al. (1971) reports that clinically intact
teeth can be maintained in the line of fracture with the use of antibiotics and stable fixation appliances. Only five percent had complications and these were minimal. Teeth in the line of fracture should be maintained unless there is evidence of root fracture, periapical pathosis, or considerable loosening of the involved teeth.

The decision to maintain a tooth in the fracture line or near the fracture line must be evaluated in each case keeping in mind the real possibility of nonunion.
Statistics on Aetiology and Incidence of Mandibular Fractures and Current Trends in Fracture Management

- References


CONCLUSIONS

Comminuted fractures of the mandible are usually the result of extreme violence and may be one of several injuries sustained by a patient. This is particularly relevant to those patients involved in high-speed traffic accidents or to those sustaining a 'war injury', such as from a grenade, exploding mine or a bullet. The overall management of this type of patient will require close co-operation between several medical and surgical specialists.

Quite often, treatment of the fracture is more complex than for a 'simple' fracture of the lower jaw and usually involves the application of several techniques. Careful planning is always required before a method or methods of fixation and immobilisation of the fracture can be selected, the ultimate aim of such treatment being to restore full function and aesthetics.