

Lessons Learnt from the Management of 1500 Complex Facial Fractures

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Abstract

The lessons learnt from the management of 1500 consecutive patients with complex facial fractures have been analysed. This analysis and the major changes in treatment principles have resulted in dramatic improvement in results. The application of craniofacial surgical principles, extended exposure of the craniofacial skeleton, accurate fracture reduction with rigid internal bony fixation and primary bone graft reconstruction has revolutionised the care of these patients.

The reattachment of the soft tissue to the reconstructed skeleton provides the final link in this comprehensive one stage reconstruction.

Analysis of results has demonstrated the majority of complications and failures to be due to inadequate exposure and reduction of fractures with bone segments rigidly plated in their unreduced position. Inadequate bone grafting and failure to re-suspend the soft tissue and canthi results in post treatment deformity even if the bony reconstruction is adequate.

Adherence to the principles of reconstruction will almost always result in a one-stage correction no matter how severe the initial injury.

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Introduction

With the advent of regional trauma centres and rapid air transport systems, a larger number of patients with extremely complex craniomaxillofacial trauma are now being seen. The problem of high-velocity facial injuries with multiple facial fractures concerns the severity of the bony injury. The majority of these fractures, particularly in the midface are unstable and often have multiple comminuted segments. Segments of bone are often markedly displaced or actually dislocated and, in addition, segments and areas of bone may be so severely damaged as to preclude any form of fixation or are actually missing, having been lost through large skin or mucosal lacerations. Attempts at closed reduction or internal wire suspension of these comminuted areas result in eventual bony collapse and soft-tissue shrinkage. The traditional treatment of a bony gap is some form of external fixation to try to maintain the bone segments in their proper positions and to

allow soft-tissue healing in anticipation of secondary bone grafting. External fixation techniques will maintain the position of mandibular segments but cannot maintain the position of comminuted midfacial bony segments. The inability to stabilise these midfacial segments results in rapid soft-tissue shrinkage and makes secondary bony correction very difficult or impossible.^{1,2}

The solution to the problem of midfacial bony collapse and soft-tissue shrinkage and scarring lies in the early exposure of all fracture segments and their repair using internal fixation techniques. This will result in the re-establishment of a normal craniofacial skeletal anatomy and maintain soft-tissue expansion during healing of the face. Comminuted or missing bone is replaced by immediate bone grafting. The utilisation of these techniques will allow the repair of even the most severe injury in one stage with an insignificant increase in the rate of infection and will prevent the development of a secondary

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deformity that may be very difficult or impossible to correct adequately.³⁻¹⁶

Principles of Repair^{7,9,13}

Whenever possible, the facial injuries are repaired immediately or within the first 5 to 7 days, depending on the magnitude of coexisting multi-system trauma. Careful coordination and planning of the involved surgical disciplines facilitate early repair. Definitive repair can be delayed for up to 2 weeks, but this increases the difficulty in adequate reduction and fixation. The decrease in facial oedema and discomfort is striking following early and rigid internal fixation and repair. Once the diagnosis of a complex injury has been made, a coordinated approach based on principles derived from reconstructive craniofacial surgery is utilised.

Direct Exposure of Fractures

All fractures are exposed directly, and the degree of comminution and displacement and the patterns of the fractures are accurately assessed by direct inspection. It is essential to expose all fractures, since only this allows the exact fracture pattern to be assessed and the position of each bony fragment or bone segment in relation to its neighbouring segment to be assessed directly. Only then can a logical plan for repair be formulated.

Failure to expose all fractures and bone segments adequately will, not infrequently, result in bone segments being stabilised in their **unreduced** or displaced position because of the fact that the surgeon can only assess each fracture site individually. This is particularly true in the orbital region, where supposed reduction of fracture segments through small incisions can be easily accomplished without the realisation of other fractures and displacements elsewhere in the region. This will result in the development of severe secondary deformities, particularly in the orbital and nasoethmoid regions (Figs. 1 & 2).

Reduction and Internal Fixation

All fractures are now reduced and internally fixed with meticulous interosseous fixation that links fragments and bone segments to adjacent fragments and to areas of intact craniofacial skeleton until mechanical stability is obtained. This may involve fixation with interosseous wiring or metal plates and screws, where necessary. In children, resorbable plating systems may be used.

Primary Bone Grafting¹³

All severely damaged or absent bone is replaced, whenever possible, by means of immediate bone grafting. Deficits in bony contour can be similarly augmented at the time of initial repair.

The use of these techniques will allow the repair of

even the most severe injuries in one stage and minimise the occurrence of secondary deformities. External fixation techniques are rarely needed, and internal craniofacial suspension wires are never used.

Incisions and Approaches

Whenever present, pre-existing lacerations are utilised in combination with planned incisions, as required. All incisions are linked to each other subperiosteally to provide direct visualisation of the entire involved facial skeleton. No attempt is made to preserve periosteal attachment to small segments of bone, since this compromises the adequacy of exposure. Only this approach will allow direct access to all fractures and facilitate adequate reduction and fixation.

The coronal incision is utilised for access to the upper craniofacial skeleton and zygomatic arch. In combination with local eyelid incisions and an upper buccal sulcus degloving incision, direct access to the entire craniofacial skeleton can be obtained.

Principles of Fixation

The status of the zygomatic arch is the key to the repair of complex orbitozygomatic and midfacial injuries (Fig. 3).⁶ The position of the zygomatic arch in between its temporal attachment posteriorly and the zygomatic body and lateral orbit anteriorly predetermines the position of the lateral and midfacial bones. A careful review of our early patients treated with extensive midfacial fixation and immediate bone grafting without zygomatic arch fixation has shown, in a significant number, late flatness of the zygomatic bodies and **midface** and an obvious shortening of the zygomatic arch both clinically and on X-ray. In all complex orbitozygomatic and midfacial fractures that show a shortening or loss of projection of the zygomatic arch on axial CT scanning, it is essential to first stabilise the zygomatic arch. Careful stabilisation of the zygomatic arch itself, using miniplates and lag screws in combination with miniplate fixation at the frontozygomatic suture line, will produce exact restoration of zygomatic body and lateral orbital wall projection in relation to the cranial base. This produces an intact outer facial frame. The inner facial frame, composed of the orbital rims, naso-orbital ethmoid, and maxillary buttresses, can now be exactly repositioned within this outer facial frame, producing an exact **three-dimensional** anatomic reconstruction with normal midfacial projection (Fig. 4).⁶

All fractures are exposed and reduced, linking each fragment to its adjacent fragment, until all links in the chain are restored. With an intact mandibular arch, correct maxillary-mandibular occlusion is re-established first. Reduction and repair are commenced with the zygomatic arch and lateral orbit. This results in reconstruction of an outer facial frame with restoration of

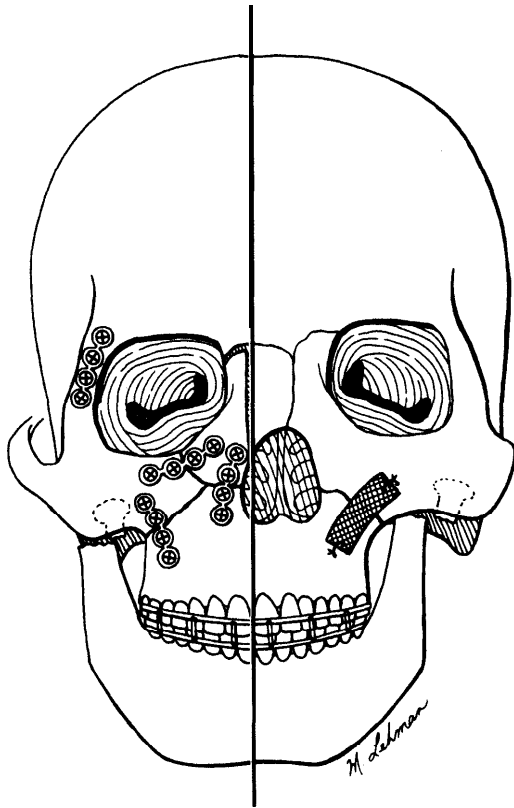


Fig. 1. Artist drawing of commonest problem now seen in facial fracture repair. Failure to adequately reduce fractures results in all fractures being rigidly fixed in their unreduced position. One of the commonest fractures mistreated is a heminaso-ethmoid fracture associated with an orbital zygomatic fracture on the same side, and this causes the entire orbital zygomatic complex to be rigidly fixed in the wrong position. Then by seeming accurate restoration of the occlusion and midfacial buttresses, everything is now rigidly fixed to the right of the midline, because this patient, in addition, has bilateral condylar neck fractures. Failure to adequately reduce even one fracture with the subsequent use of rigid fixation will cause a progressive fixation of each individual fracture in the wrong position.

vertical and transverse facial height. Anterior, posterior, or horizontal facial height and projection is re-established by reduction and fixation of the inferior and medial orbits, nasoethmoid, nose, and central maxillary fractures within this previously established facial frame.

When fractures of the mandibular symphysis, or body, are present, continuity of the mandibular arch is re-established by rigid internal fixation using lag screws and compression or reconstruction plates. It is essential in the repair of all facial fractures that involve the upper or lower dental arch to re-establish the correct occlusion prior to the application of plate or screw fixation, since failure to do this will maintain stabilised segments in their wrong position, and it is impossible to move these stabilised segments secondarily by any orthodontic means.

Primary Bone Grafting¹³

All severely damaged or missing bone is replaced and contour deficits are augmented whenever feasible, by

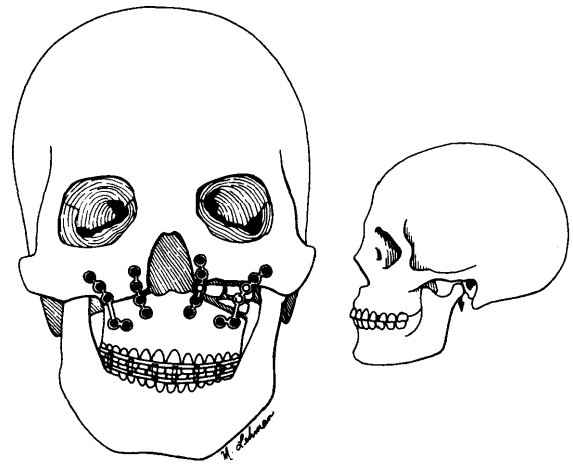


Fig. 2. Illustrates the importance of condylar positioning in the fossa prior to fracture fixation. Even with an intact mandible, it is possible to dislocate the condyl out of the fossa and with the patient in what seems like normal occlusion, the fractures can be fixed with the condyl dislocated out of the fossa and when the patient is taken out of occlusion, a malocclusion will result.



Fig. 3. Zygomatic arch is the key to accurate reconstruction of the orbital zygomatic and midfacial region. The view of the base of the skull showed the importance of the zygomatic arches, which are the direct link from the base of the skull to the midface. The position of the zygomatic arch predetermines the correct facial width, as well as midfacial projection. This is independent of the occlusion. The zygomatic arch is completely flat at its midportion and is only curved at its posterior and anterior aspects. If the zygomatic arch is fixed as a true arch, it will result in a widening of the midface with lack of projection of the zygomatic body.

immediate bone grafting. Only in the presence of a heavily contaminated or infected wound or in the absence of adequate soft-tissue cover may the bone grafting be delayed. In our experience, bone grafting performed at the time of the original repair always gives superior result as compared with secondary bone grafting, the result of which is usually compromised by soft-tissue shrinkage and scarring.

In the majority of patients with craniofacial trauma, split calvarial bone grafts have become our primary source of graft material. However, these are difficult to use and contour in extensive orbital wall defects or if there is extensive bone loss, such as in gunshot wounds. In these situations, we combine the use of split calvarial

grafts with split rib grafts, which are easier to bend and shape to large contour deficits of the orbital cavity and very large defects in the maxilla and zygomatic regions and skull.

Split skull and split rib grafts have yielded a readily available source of bone-grafting material and have been associated with minimum morbidity and complications. These grafts have an exceptional ability to survive, even if portions of the graft are exposed to the air or through the mucosal lining of the nose or oral cavity, and the risk of possible graft exposure in patients with severe soft-tissue and bony injuries should not preclude their use. Soft tissue injuries should not preclude their use. Bone grafts, especially in the midface and nasal area, will maintain soft-tissue expansion and projection, even if the segments become exposed. In this situation, they act as an internal splinting mechanism, maintaining the normal stretch and position of the soft tissue during soft-tissue healing and scar maturation. Bone grafts used to reconstruct the anterior wall of the frontal sinus, medial wall and floor of the orbit, and anterior wall of the maxilla survive adequately even though they are placed over an open cavity with healthy soft-tissue coverage on one side only. The failure to use bone grafts will result in rapid shrinkage of soft-tissue and make subsequent reconstructive efforts difficult and often inadequate.

Adequate fixation of bone grafts is essential, since inadequate fixation predisposes to infection or resorption. Bone grafts are stabilised, whenever possible, using lag screws or miniplates. The addition of lag-screw fixation to bone grafts has added a new dimension to the stability of midfacial reconstruction. Bone grafts, either calvarial or rib, that are stabilised with lag screws undergo minimal resorption. Most bone grafts used to reconstruct the orbital cavity require no form of fixation and are merely wedged into place and held there by the orbital contents.

Applied Principles³⁻⁵

Orbitozygomatic Fractures (Fig. 5)

Injuries to the midface may result in fractures of the orbitozygomatic complex. These fractures may be isolated or may be combined with other midfacial injuries. Orbitozygomatic fractures are wrongly termed tripod fractures and should always be considered as quadrupod fractures, since the fourth site of fracture, the zygomaticomaxillary buttress, is one of the keys to understanding and managing unstable zygomatic fractures. This lateral buttress acts as a direct antagonist to the pull of the masseter muscle and forms the structural support to the zygoma itself. Fractures of this buttress will allow the zygomatic body to tilt downward and inward, resulting in late depression of the zygomatic prominence. Two-point fixation of the frontozygomatic suture line and inferior orbital rim does not prevent downward rotation

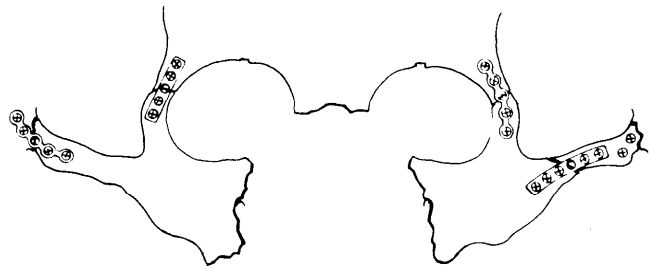


Fig. 4a. When displaced nasoethmoid fractures are associated with LeFort III fractures involving the orbitozygomatic complex, the lateral orbitozygomatic complex is carefully reduced first, using the zygomatic arch and lateral orbital wall as an index. This restores the cut or facial frame with the correct facial width and projection.

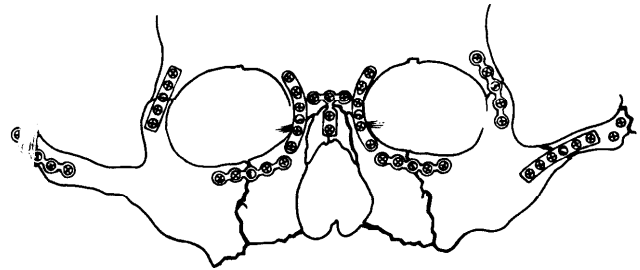


Fig. 4b. The nasoethmoid complex can now be accurately reduced within this outer facial frame. As long as there are fractures at the LeFort I level, the entire upper facial repair can be performed independent of the occlusion, although the occlusion is always used as an index whenever possible.

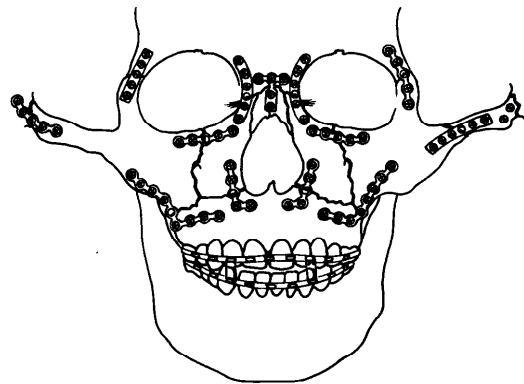


Fig. 4c. The midfacial repair is now completed by accurate repositioning of the occlusion and fixation of the midfacial fracture at the LeFort I level. Once all fixations have been completed, the occlusion can be released in most instances.

of the zygomatic body. Direct exposure by means of an upper buccal sulcus incision of this buttress and direct anatomic reconstruction with miniplates or bone grafts will prevent this complication. When the fracture has involved the zygomatic arch and has resulted in loss of anteroposterior projection of the zygoma, it is essential to stabilise the zygomatic arch as well. Miniplates are used to stabilise the frontozygomatic suture line, zygomatic arch, and zygomaticomaxillary buttress. The final point of fixation on the inferior orbital rim can be stabilised using a miniplate, microplate, or interosseous wire. In many cases, an interosseous wire is preferable because a miniplate may be felt through the thin eyelid skin. Inadequate treatment of orbitozygomatic fractures

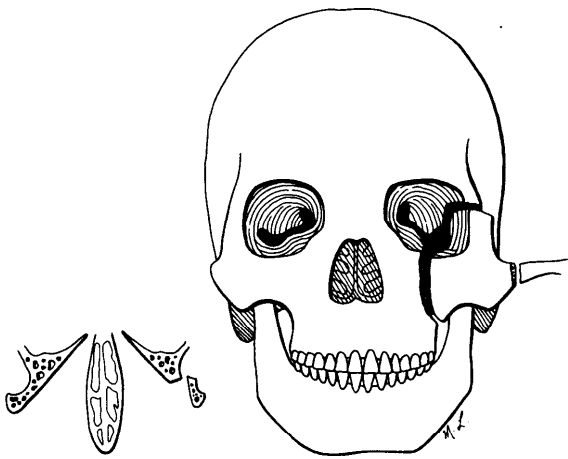


Fig. 5a. In displaced fractures of the orbitozygomatic complex, the lateral wall of the orbit is the most accurate and key index to the degree of rotation and subsequent reduction of the fracture. The lateral wall of the orbit is the thickest part of the orbital and is rarely comminuted. Accurate reduction will result in exact restoration of the lateral orbital wall.

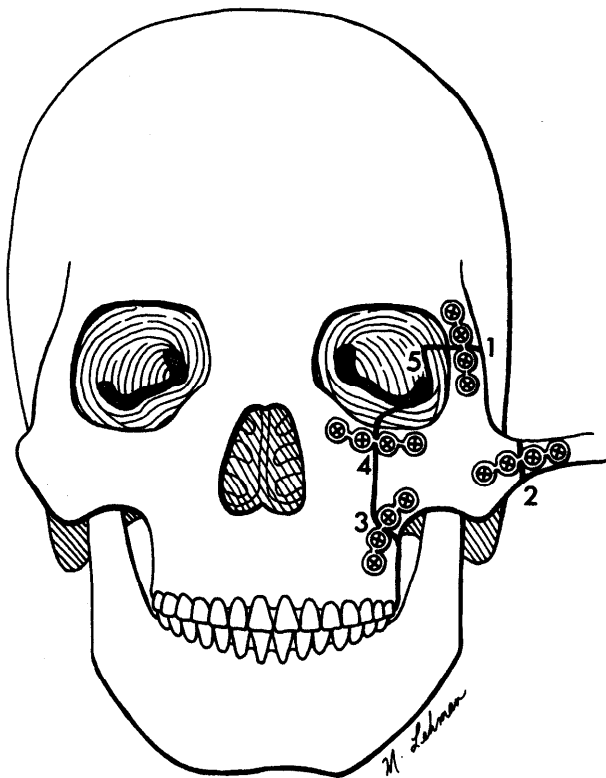


Fig. 5b. In the accurate reduction and fixation of complex displaced orbitozygomatic fractures there are thus, five possible points to assist the degree of reduction, and four possible points of fixation, numbers 1 to 4. The lateral orbital wall, number 5, is the most accurate index of correct reduction and correction of the rotation re-deformity. Fractures that involve comminution or telescoping and shortening of the zygomatic arch, in combination with fractures at the other sites, require accurate open reduction of the zygomatic arch through a coronal incision with restoration of the correct width and projection.

is the most common cause of secondary deformity following facial fractures. Coexisting orbital wall fractures should always be suspected, particularly in the medial

wall and inferomedial and lateral walls. These deficits should be carefully outlined and totally reconstructed with immediate bone grafting to prevent the late occurrence of enophthalmos and oculo-orbital displacement.

Nasoethmoid-orbital Fractures¹¹⁻¹⁵ (Figs. 6 & 7)

A direct blow to the midface may result in fractures of the bony nasoethmoid-orbital complex and injury to the adjacent soft tissues. These injuries may be confined to the nasoethmoid-orbital complex but more frequently, are associated with other facial fractures and are often complicated by multi-system trauma. The injuries result in severe cosmetic and functional deformity due to collapse of the nose, ethmoids, and medial orbits and are accentuated by coexisting injury to the medial canthal ligaments and nasolacrimal apparatus. Extension into the anterior cranial fossa with concomitant dural tear, cerebrospinal fluid rhinorrhoea, and cerebral injury may be life threatening.

Nasoethmoid-orbital fractures are the most challenging of all craniofacial fractures to treat owing to the intricate anatomy of this region and the difficulty in fracture fixation. Inadequate initial treatment will often result in severe deformity that may be extremely difficult, or impossible, to correct adequately. Optimal management involves early surgical exploration and meticulous bony and soft-tissue repair that utilises the principles learned from reconstructive craniofacial surgery. It is essential to understand that the nasal bones, vomerine bone, perpendicular plate of the ethmoid, and ethmoid labyrinth are thin and predisposed to comminuted fractures. Conversely, the nasal process of the frontal bone and frontal process of the maxilla is strong, and comminution is rare. The medial wall of the orbit, however, is extremely thin and invariably comminutes.

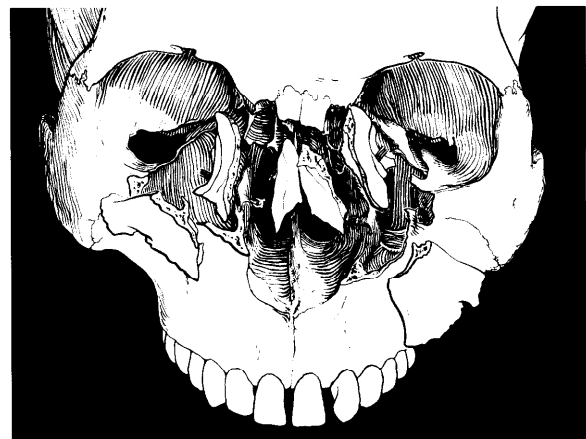


Fig. 6. Artist depiction of the typical pattern of bony injury in the bony nasoethmoid fracture. Note the strong frontal nasal buttress detached superiorly and inferiorly and displaced inferiorly and posteriorly taking the medial canthal ligament with it. The most important principle in repair is the repositioning of this bony segment and the careful dissection of the segment prior to fixation to maintain the attachment of the ligament.

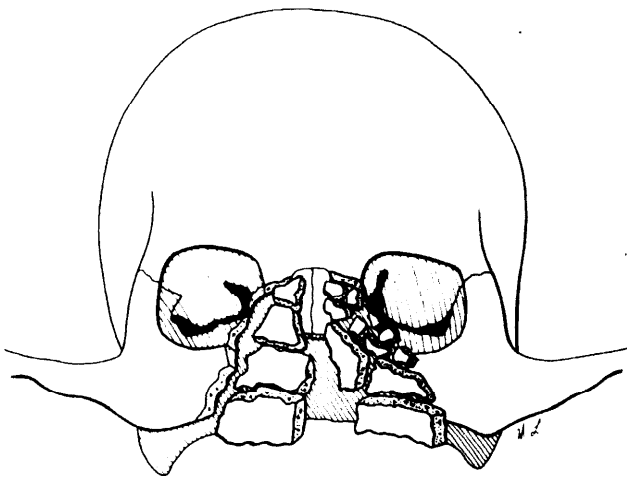


Fig. 7a. The right nasal orbital region shows a multi-segmental comminuted fracture. The left side shows a significant comminuted fracture with bone destruction and loss.

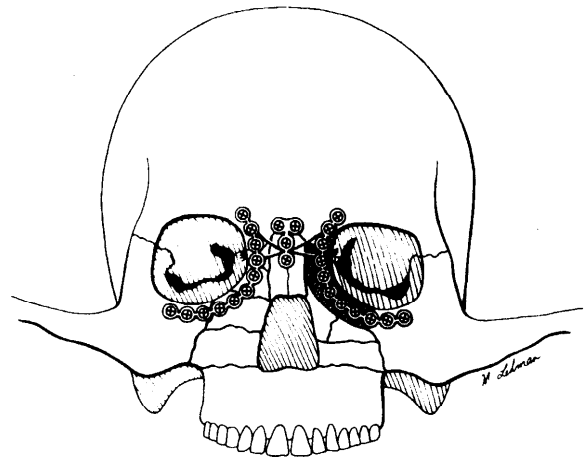


Fig. 7b. These fractures are repaired with 3-dimensionally bendable mini-adaption plates. On the right side with multiple segmental fractures the adaption palate is carefully bent to the shape of the orbital rim. This can be done in situ or the plate can be contoured on a skull model. The plate can then be sterilised and anchored superiorly to the intact frontal bone and inferiorly to the lateral portion to the orbital rim with at least two screws on either side. The intervening comminuted segments are brought up to the plate and lagged to the plate with screws, thus re-establishing the contour. In comminuted fractures such as these, the ligament is either lost or has to be stripped to allow adequate exposure and fixation. The ligament must be re-wired trans-nasally. On the left side where the nasoethmoid segment is lost, the plate is bent in a similar fashion and attached both superiorly and inferiorly with at least two screws. A bone graft is now taken carefully contoured to the shape of the missing nasoethmoid complex and fixed to the overlying plate with multiple screws. Deep orbital and nasal bone grafting is then performed as needed.

Telecanthus is nearly always produced by the splaying apart of the nasomaxillary buttress, which is displaced laterally and downward, taking the medial canthal ligament with it. It is extremely rare for the ligament to be actually lacerated or avulsed from the bone. Correct anatomic repair of the nasomaxillary buttress allows restoration of a correct intercanthal distance. Attempts at holding this segment in place with multiple interosseous wires rarely have been successful in our experience. The stabilisation of this segment with miniplates, both above (thereby attaching it to the region of the frontal bone and frontal sinus) and below (attaching it to the intraorbital rim), results in a three-dimensionally stable reconstruction with restoration of a correct intercanthal distance. The miniplate can be placed adjacent to the canthal ligament itself, which should be isolated in all cases during medial rim and orbital wall dissection. It is essential not to strip the ligament off the bone during this dissection because it will then have to be rewired to the nasal bone. A transnasal canthopexy, in our experience, rarely gives a perfectly natural appearing medial canthal region. When there is loss of distal nasal support, a cantilever bone graft should be used to restore nasal projection and prevent soft-tissue shrinkage. A split calvarial bone graft is preferred, and this is cantilevered by means of a miniplate and is fixed to the anterior portion of the frontal bone. The degree of cantilevering can be varied by adjustment of the angle of the bend in the miniplate. Split calvarial grafts, rigidly fixed and cantilevered in this fashion, rarely undergo resorption and produce an excellent long-term nasal reconstruction.

Combined Injuries of the Cranium and Face⁹⁻¹¹ (Figs. 8 & 9)

Various technical factors are important in the reconstruction of this region:

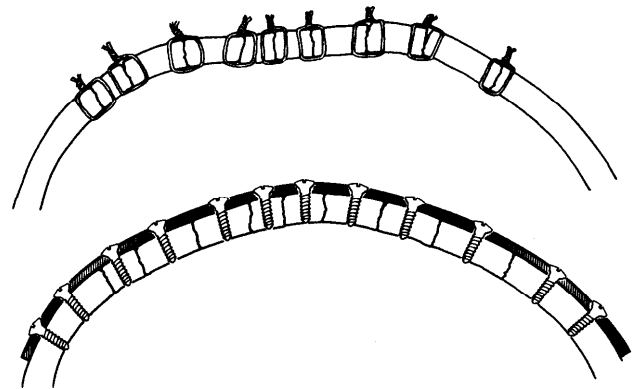


Fig. 8. With multiple segmental and comminuted fractures of the frontal orbital region and skull, it is difficult to maintain the correct contour and shape of this region with simple interosseous wiring. Plates and screws allow the exact contour restoration by fixing the palate to the stable edges on either side and then lagging each intervening fragment up to the plate using a screw placed into each segment individually. This will maintain the correct contour counteracting the forces of the healing soft tissue.

1. With severe comminution of the cranial vault, it is essential to first stabilise the cranium with rigid interosseous fixation. The facial bones can then be stabilised and fixed to the now intact cranial vault.
2. With massive comminution or actual loss of cranial bone, a reverse order of fixation is used. The facial fractures are fixed first, and the face is stabilised to the residual cranial vault. The amount of missing bone can now be assessed and replaced with primary bone grafting using either split cranial or split rib grafts.

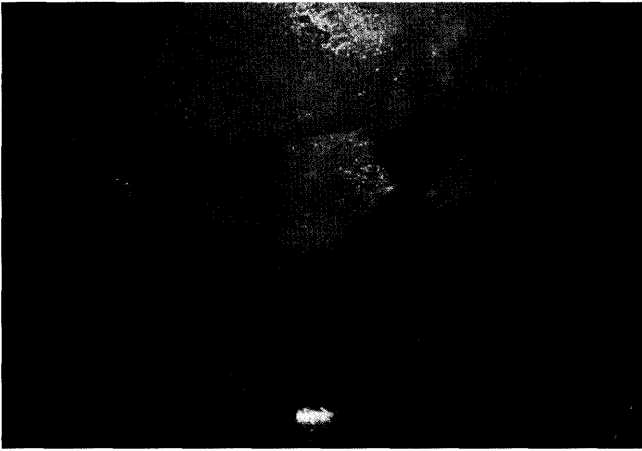


Fig. 9a. Patient with comminuted complex segmental fractures of the frontal nasal orbital complex.



Fig. 9b. The entire complex can be removed and pieced together on the back table while the neurosurgeon is completing the intracranial repair.



Fig. 9c. Once this has been done, the entire complex can then be replaced into the craniofacial skeleton and the remainder of the repair completed.

3. Inadequate reconstruction of the supraorbital ridge commonly leads to flatness in this region. The use of a full-thickness rib graft or stacking of bone grafts in layers prevents this.
4. Injury to the orbital roof may result in isolated fractures, comminuted fractures, or areas of bone de-

struction or loss. Concomitant loss of the posterior wall of the frontal sinus results in direct communication between the anterior cranial fossa and orbit. The orbital roof should always be reconstructed in this situation to separate the two cavities. When the posterior wall of the frontal sinus is intact, it is not necessary to reconstruct small defects of the orbital roof. However, failure to reconstruct larger defects, even with the posterior wall of the frontal sinus intact, may lead to herniation and entrapment of orbital contents and possible enophthalmos and diplopia.

5. When the frontal sinus injury is associated with severe injury at the base of the frontal sinus with direct communication between the ethmoids and frontal sinus, a pericranial, galeal, or galeofrontalis flap is inserted into the frontal sinus and placed along the floor of the sinus to separate the nasal and cranial cavities. The frontal sinus itself is obliterated by placing separate bone plugs in the region of the frontonasal ducts and packing the remainder of the sinus cavity with cancellous bone from the skull diploe or iliac crest.

Fractures of the cranial vault are not under the influence of muscle pull and tension, as opposed to fractures influencing the tooth-bearing areas of the craniofacial skeleton. Thus, the same degree of rigid internal fixation is not essential in this area. Interosseous wires play a useful part in the management of comminuted areas of cranial bone. However, miniplate fixation has proved extremely useful in the management of comminuted areas of cranial bone. However, miniplate fixation has proved extremely useful in the management of significantly large and segmental fractures of the cranial vault. Long miniplates can be exactly contoured to the shape of the skull, and individual fragments can be lagged to the plate with specially designed miniscrews that are only 3 and 4 mm in length so as to prevent them from entering the cranial cavity and damaging the dura. Our preference now, in the face of markedly comminuted segments of the anterior cranial vault, is to replace these primarily with split calvarial grafts held in place at selected sites with miniplates. This gives an exact reconstruction of a normal cranial skeletal contour and greatly minimizes the occurrence of secondary deformity.

Maxillary Fractures^{12,16-18} (Figs. 10 to 13)

The paired nasomaxillary, zygomaticoaxillary, and pterygomaxillary buttresses maintain the position of the maxilla in relation to the cranial base above and the mandible below. Exact anatomic reconstruction of the four anterior buttresses, namely, the nasomaxillary and zygomaticomaxillary buttresses, allows exact repositioning of the maxilla in its correct anteroposterior position in relation to the cranial base and allows

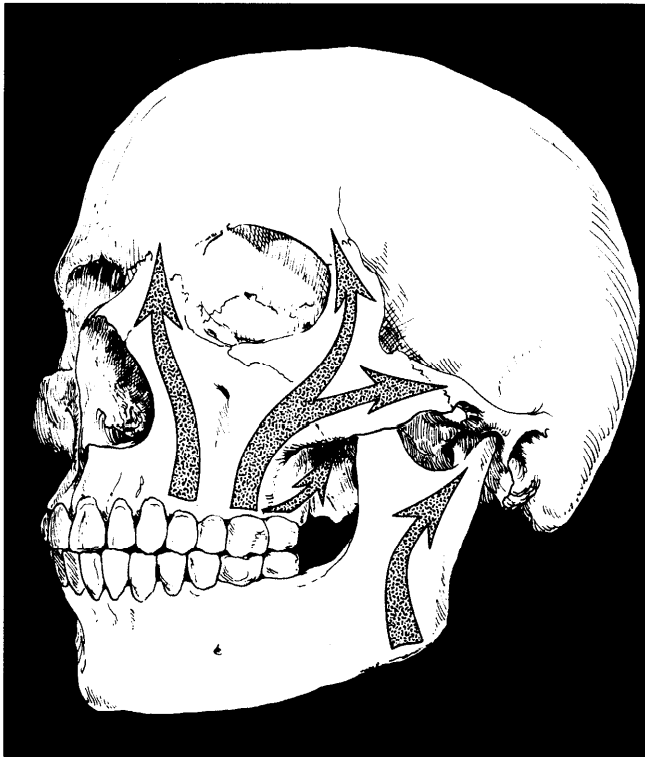


Fig. 10. The midfacial bones are connected by a system of buttresses to the base of the skull. The most important principle in the repair of LeFort-type maxillary fractures is to re-establish the correct occlusion and then reposition the midfacial bones in relation to the skull base above, and the mandible below. The maxilla is reconstructed by anatomical reconstruction of the four anterior maxillary buttresses.

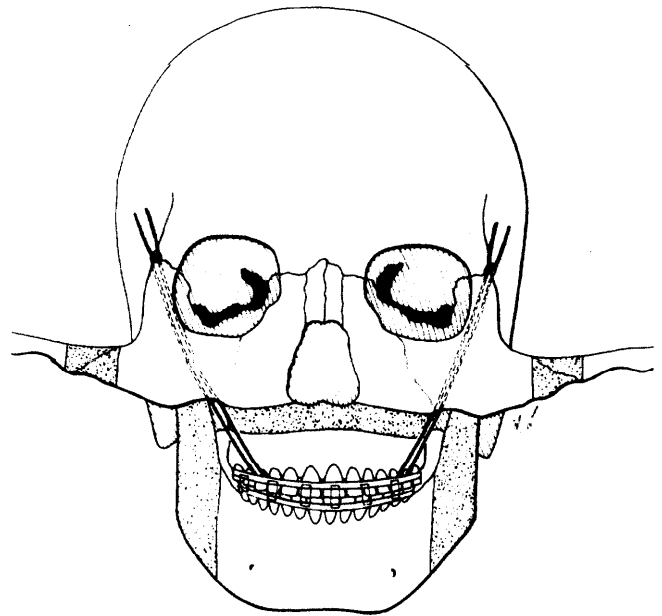


Fig. 11. In complex panfacial fractures, there are certain sites of fracturing that may lead to complication. The first is the region of the anterior maxillary buttresses, which in some patients may be thin and may be severely comminuted. The application of internal suspension wires will cause this area to collapse and lead to telescoping of the midface. Rigid internal fixation with primary bone grafting when necessary will restore the correct position of these buttresses and maintain midfacial projection. The second area of problem is the zygomatic arch and the third area causing problems is fractures occurring in the ramus region of the mandible which may lead to the shortening of the vertical height of the mandible.

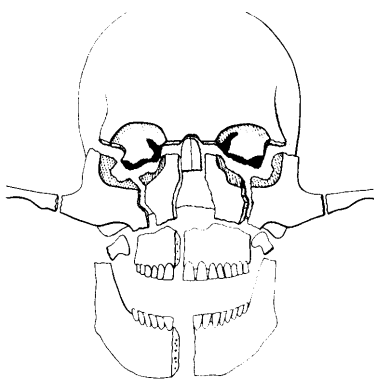


Fig. 12a.

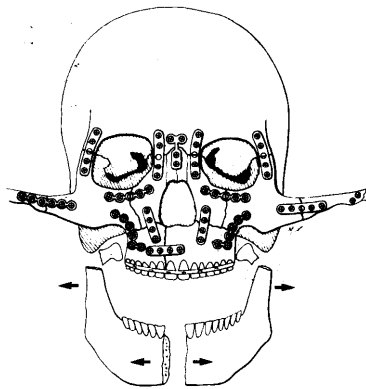


Fig. 12b.

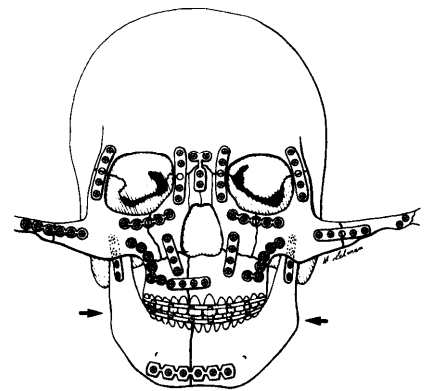


Fig. 12c.

Fig. 12a. In panfacial fractures, the midfacial fractures may be associated with sagittal splitting of the palate and multiple-mandibular fractures, commonly a parasymphiseal fracture and bilateral condylar neck fractures. In this situation all reference points are lost and the major difficulty is the restoration of the correct facial width.

Fig. 12b. The only accurate reference point remaining is the restoration of the correct facial width by accurate reconstruction of the zygomatic arches and lateral facial frame to the skull base. The facial repair is then completed as before. This brings the lateral and medial maxillary buttresses into proper alignment and ensures the correct upper and midfacial widths.

Fig. 12c. The correct maxillary width can now be related to the position of the maxillary buttresses and by placing the patient in occlusion, the correct mandibular width can be set as well. Rigid fixation is required at the parasymphiseal fracture and is often aided by fixation at the bilateral condylar neck fractures. With these parasymphiseal and bilateral condylar neck fractures there is marked display of the mandible causing a tremendous increase in lower facial width. Assessment of this fracture at the paraempiphysal region alone will often result in the mandible being fixed in its widened position, as only the buccal cortex of the mandible can be visualised. Accurate restoration of mandibular width is accomplished by pushing inwards at both angles prior to the application of the parasymphiseal plate. This will ensure the correct restoration of lower and thus, upper facial width.

reconstruction of the exact vertical height and horizontal projection of the maxilla. No reconstruction of the posterior buttress is needed because the four anterior buttresses will maintain the correct position of the maxilla.

The intact mandible provides an additional buttress in relation to the cranial base, and the re-establishment of normal maxillary and mandibular occlusion will provide additional support to the reconstructed maxilla.

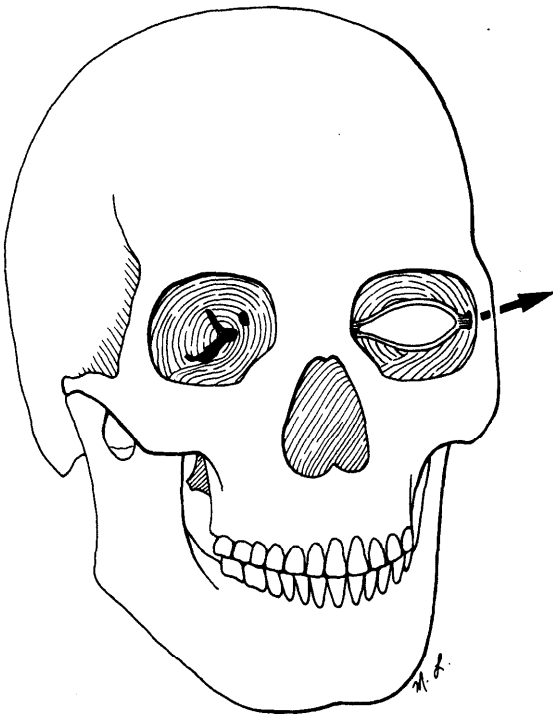


Fig. 13. At the end of all the bony fixation and repair, soft tissue has to be repositioned to the craniofacial skeleton using sutures placed through multiple drill holes, as well as repositioning of the lateral canthal tendon to the inside of the lateral orbit.

The anterior maxillary buttresses are exposed through an upper gingival buccal sulcus degloving incision. All unstable buttresses are repaired with miniplates, and missing buttresses are replaced with bone grafts fixed in place with lag screws. When the fractures that cross the buttresses are low and situated close to the tooth-bearing bone, care must be taken not to place screws through the tooth apices. In this situation, it may be necessary to use small-bone grafts to reinforce the buttress repair, since the lag screws can be placed exactly between the tooth apices.

Complex Mandibular Fractures^{17,18}

Internal fixation of mandibular fractures using compression plating, lag screws and reconstruction plates has revolutionised management of complex mandibular injuries. These techniques are particularly useful in the care of the polytraumatised patient with associated head injuries and cervical spine fracture. In addition, stabilisation in the comminuted or segmental fracture or the mandibular fracture with bone loss is facilitated.

Airway management is facilitated by using rigid internal fixation techniques with plates and screws. In midfacial or mandibular injuries in the multiple trauma patient or in combined of the midface and mandible, the orotracheal tube can be pushed to the side, thereby allowing temporary IMF to establish the correct occlusion. Following rigid internal fixation of the mandible

and midface with plates and screws, in combination with immediate bone grafting where necessary, the IMF can often be released. This allows endotracheal intubation to be maintained postoperatively until a patient airway is ensured. Tracheostomy is only needed in the patient with bilateral fractures, where the position of the mandible has to be maintained in relation to the maxilla. The ability to repair multiple facial fractures without the need for intermaxillary fixation has revolutionised the care of the multiple-trauma patient. This allows airway management in the early postoperative phase without the need for tracheostomy in the majority of patients.

Gunshot Wounds⁸

Gunshot wounds of the face often present as formidable wounds that offer a great challenge to the reconstructive surgeon. Frequently, there is both bony and soft-tissue loss, with the bony loss usually more severe. This may be further complicated by concomitant injuries to the oral cavity, nasal passages, orbits, cranial cavity, and their contents. Lessons and techniques learned in the management of complex facial trauma using craniofacial surgical techniques, immediate bone grafting, and rigid internal fixation with plates and screws in the midface and mandible can be successfully applied to the management of severe gunshot wounds of the face. Extensive bone loss is replaced using rib and cranial grafts stabilised with lag screws and miniplates. The use of extensive miniplate and lag screw fixation in the midface and large reconstruction plates in the mandible to bridge bone gaps facilitates stabilisation and reconstruction in these areas in combination with the bone grafts. Soft-tissue repair can be by means of various local or regional flaps or, in massive soft-tissue loss, by means of a free vascularised omental flap that can be wrapped around the bone grafts. Total nasal reconstruction, with the use of tissue expanded forehead skin, provides an ideal method of nasal reconstruction once initial midfacial reconstruction projection has been obtained.

Primary bone grafting in mandibular gunshot wounds has a high complication rate as the intraoral seal cannot be guaranteed. The use of strong reconstruction plates can bridge a bony gap, allowing delayed bone grafting once the intraoral lining has healed. Immediate bone grafting is always done in the midface, which is away from the salivary stream.

REFERENCES

1. Merville L. Multiple dislocation of the facial skeleton. *J Maxillofac Surg* 1974; 2:187.
2. Merville L C, Derome P. Concomitant dislocations of the face and skull. *J Maxillofac Surg* 1978; 6:2.

3. Antonyshyn O, Gruss J S. Complex orbital trauma: The role of rigid fixation and primary bone grafting. *Adv Ophthalmic Plast Reconstr Surg* 1987; 7:61.
4. Antonyshyn O, Gruss J S, Galbraith D J, Hurwitz J J. Complex orbital fractures: A critical analysis of immediate bone graft reconstruction. *Ann Plast Surg* 1989; 22:220.
5. Gruss J S, Phillips J H. Complex facial trauma: The evolving role of rigid fixation and immediate bone graft reconstruction. *Clin Plast Surg* 1989; 16:93.
6. Gruss J S, Van Wyck L, Phillips J H, Antonyshyn O. The importance of the zygomatic arch in complex midfacial fracture repair and correction of post-traumatic orbitozygomatic deformities. *Plast Reconstr Surg* 1990; 85:878.
7. Gruss J S. Complex craniofacial trauma: Evolution of management, a trauma unit's experience. *J Trauma* 1990; 30:377.
8. Gruss J S, Antonyshyn O, Phillips J H, Grothaus P. Early definitive bone and soft tissue reconstruction of major gunshot wounds of the face. *Plast Reconstr Surg* 1991; 87:436.
9. Gruss J S, Bubak I, Egbert M. Craniofacial fractures: An algorithm to optimize results. *Clin Plast Surg* 1991; 19:195.
10. Gruss J S. Fronto-naso-orbital trauma. *Clin Plast Surg* 1982; 9:557.
11. Gruss J S. Nasoethmoid-orbital fractures: Classification and role of primary bone grafting. *Plast Reconstr Surg* 1985; 75:303.
12. Gruss J S, MacKinnon S E. Complex maxillary fractures: Role of buttress reconstruction and immediate bone grafts. *Plast Reconstr Surg* 1986; 78:9.
13. Gruss J S, MacKinnon S E, Kassel E E, Cooper P W. The role of primary bone grafting in complex craniomaxillofacial trauma. *Plast Reconstr Surg* 1985; 75:17.
14. Gruss J S, Pollock R A, Phillips J H, Antonyshyn O. Combined injuries of the cranium and face. *Br J Plast Surg* 1989; 42:385.
15. Markowitz B L, Manson P N, Sargent L, Vander Kolk C A, Yaremchuk M, Glassman D, et al. Management of the medial canthal tendon in nasoethmoid-orbital fractures: The importance of the central fragment in classification and treatment. *Plast Reconstr Surg* 1991; 87:843.
16. Gruss J S. Advances in craniofacial fracture repair. *Scand J Plast Reconstr Hand Surg Supp* 1995; 27:67-81.
17. Rosen H M. Miniplate fixation of Le Fort I osteotomies. *Plast Reconstr Surg* 1985; 78:748.
18. Schilli W, Ewers R, Niederdelman H. Bone fixation with screws and plates in the maxillofacial region. *Int J Oral Surg* 1981; 10(Suppl 1):329.