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Sequential surgical treatment for panfacial fractures and significance of biological osteosynthesis

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Abstract – The goal of this retrospective study was to evaluate the efficacy of panfacial fracture repair and to review guidelines for treatment based on AO/Arbeitsgemeinschaft fuer Osteosynthesefragen Association for Study of Internal Fixation theories of biological osteosynthesis. Sixty-eight patients with panfacial fractures were subjected to preoperative X-ray cephalometric analysis and model surgery, followed by open surgical reduction, rigid internal fixation and at least 8 weeks of clinical follow up. A variety of surgical approaches were used, with the 68 patients undergoing a total of 93 surgical procedures. In all but eight patients, the treatment produced satisfactory correction of maxillofacial deformities and restoration of normal function. Among the eight patients whose treatment was not deemed successful, there were two whose facial deformities were not corrected by treatment. In addition, there were five patients with enophthalmos or motor disturbance of the eye that failed to show improvement during the study, and four patients who exhibited signs of limited mouth opening and malocclusion. The systematic and sequential choices of surgical methods were key factors in determining panfacial fracture treatment outcomes. We propose that treatment of bone fractures must take into account the biological characteristics of the damaged bone to facilitate selection of appropriate plate and screw systems and repositioning methods.

Panfacial fractures present remarkable challenges to both surgeon and patient. These fractures, affecting the upper, middle and lower regions of the face (1, 2), are often associated with soft tissue injuries and loss of bone structures. Severe panfacial fractures can lead to complicated facial deformities, malocclusion and limited facial movement. Importantly, panfacial injuries can impact the psychological state of the patient or limit social rehabilitation, sometimes permanently. Treatment of panfacial fractures can be difficult, because there are often no available stable structures to use as a focal point to re-establish bone continuity. Facial reconstruction treatment programs and principles of management are thus unique (2, 3), but are not without considerable controversy (3–7).

Surgical approaches that focus first on facial width, followed by stabilization of lateral regions, have been proposed (2, 3). These approaches begin treatment at the inferior division of the central zone. Next, lateral zones are defined by the locations of the frontal bar, zygomatic arch, malar eminence and mandibular angles. Another common approach, focusing on repair of the zygomatic arch, is referred to as the outside-to-inside approach (6). An outer frame intended to correct facial width is first produced through reduction and repair of the zygomatic arches followed by repair of upper and inner frames within this outer frame. It is important that reconstruction of lateral and medial buttresses is close to the correct midface and projection. The third common approach is the top-to-bottom approach (7). According to this strategy, repair begins at the forehead and progresses to the midface, and then the mandible. Nasofrontal structures are aligned with the orbital rims to achieve the proper transverse dimension and then the zygomatic arches are reduced to achieve a suitable sagittal dimension. Finally, the maxilla and mandible are realigned centrally to re-establish facial height and projection.

No randomized studies that examine the differences in surgical approaches have been reported to date. In this study, we performed a retrospective case review of 68 patients who presented with panfacial fractures to examine surgery treatment principles. In particular, we evaluate the significance of biological osteosynthesis (BO) (8), which, while not conflicting with AO/Association for Study of Internal Fixation (AO/ASIF) principles, attaches more importance to the preservation of soft tissue and blood circulation to facilitate healing (9).

Patients and methods

Subjects

Sixty-eight patients with panfacial fractures were treated at the Department of Oral & Maxillofacial Surgery of the

West China College of Stomatology, Sichuan University, between 2002 and 2006. Of these patients, 46 (67.6%) were between the ages of 21 and 40. Mechanisms of injury were road traffic accidents in 31 patients (45.6%), inter-personal violence in 16 patients (23.5%), falls in 13 patients (19.1%), and sport-related or other accidents in eight patients (11.8%).

Clinical and radiological data from patients were retrospectively analyzed at follow-up intervals of 1, 3, 6 and 12 months. Data analyzed included patient age and gender, treatment type, location of fractures, concomitant maxillomandibular fixation (MMF) and its duration, surgical approach used and any complications (Tables 1 and 2).

Therapeutic design and preliminary testing

Model surgeries were performed for all patients using Helical 3D images, X-ray cephalometric analysis and model analysis. The distance and direction of each model segment's movement were recorded (data not shown). The severity of facial deformities and malocclusions was estimated, and surgical incision sites were predicted. Finally, the direction of bone segment movement and the size and shape of bone grafts were estimated.

Surgical techniques

Analysis of examination results suggested that both the causes and severity of facial deformities and dysfunctions were taken into account during preoperative planning. Fracture locations (Table 1) determined whether each segment was sequentially repositioned and fixed from outside to inside and/or bottom to top. For instance, in cases with both zygomaticomaxillary complex (ZMC) and mandible fractures (36/68, 52.9%), after reduction and fixation of condyles and other mandibular fractures to re-establish facial height and projection, the zygomas were reduced and fixed using the sphenozygomatic suture, zygomatic arch and zygomaticomaxillary sutures as guides. Finally, maxillas were stabilized along the zygomaticomaxillary buttress. In cases with both ZMC and nasal-orbital-ethmoid (NOE) fractures (11/68, 16.2%), the zygomatic arches were first reduced to create a suitable sagittal dimension, then the maxilla and the orbital rims were realigned to achieve the proper transverse dimension, and finally normal dorsal nasal projection and contour were restored, as were the intercanthal distance and medial canthal soft tissue relationships.

Results

Clinical treatment data

Several methods of reduction and fixation were used in the treatment of panfacial fractures. All clinical data are shown in Table 2. Fifty patients (73.5%) were treated with metal arch bars for intermaxillary traction before the fractures had healed. In the presence of unilateral or bilateral condylar fractures, or comminuted or old fractures, MMFs were used for an additional 2–3 weeks.

Postoperative observations

In all but eight patients, maxillofacial deformities were corrected and normal occlusion was restored (average degree of maximal interincisal opening was 38.1 ± 2.7 mm). Among those whose treatment was unsuccessful, facial deformity was apparent in two patients, while five patients showed enophthalmos or motor disturbance of the eye. Six patients had light, postoperative malocclusion rectified by subsequent orthodontic treatment, three patients had temporary frontal muscle paralysis and two patients had zygomaticotemporal tissue atrophy.

Table 1. Clinical findings for 68 patients with panfacial fractures

Fracture locations	*n* (%)	Mandibular fractures	Patient age (years)	Patient gender	Treatment type: Primary	Treatment type: Secondary	Bone loss
ZMC and mandibular	36 (52.9%)	Single-sided condyle fractures: 27 Double-sided condyle fractures: 5 TMJ dislocation: 4	14–67	Male: 29 Female: 7	19	17	
ZMC and NOE	11 (16.2%)		16–60	Male: 4 Female: 7	6	5	
ZMC, mandible and NOE	9 (13.2%)	Single-sided condyle fractures: 4 Double-sided condyle fractures: 3 TMJ dislocation: 2	15–63	Male: 4 Female: 5	3	6	Condyle process defects: 2
Frontal bone or/and frontal sinus, ZMC fractures	7 (10.3%)		23–51	Male: 5 Female: 2	1	6	Zygomatic bone defects: 2
Frontal bone or/and frontal sinus, ZMC and mandibular fractures	5 (7.4%)	Single-sided condyle fractures: 2 Double-sided condyle fractures: 2 TMJ dislocation: 1	26–49	Male: 4 Female: 1	0	5	Periorbital bone defects: 3
Total	68	50	15–64	Male: 46 Female: 22	30	39	

ZMC, zygomatic maxillary complex; NOE, nasoethmoidal fractures; TMJ, temporomandibular joint.

Table 2. Clinical treatment data for 68 patients with panfacial fractures

Fracture locations	Procedure	Surgical approach	Significant complications	Duration of MMF
ZMC and mandible	From bottom to top and from outside to inside, after reduction and fixation of condyles and other mandibular fractures to re-establish facial height and projection, the zygomas were reduced and fixed using sphenozygomatic suture, zygomatic arch and zygomaticomaxillary sutures as guides. Finally, maxillae were stabilized along the zygomaticomaxillary buttress	The coronal + lower eyelid or transconjunctival + intraoral + preauricular or retromandibular incisions	Craniocerebral injury: 4 Diplopia: 4 Blindness or blurred vision: 1 Facial nerve injury: 2 Oculomotor paralysis: 3	2 or 3 weeks
ZMC and NOE	From outside to inside: first reduction of the zygomatic arches to create a suitable sagittal dimension, followed by the realignment of the maxilla and the orbital rims to achieve proper transverse dimension, and finally restoration of normal dorsal nasal projection and contour, and restoration of the intercanthal distance and medial canthal soft tissue relationships	The coronal + lower eyelid or transconjunctival ± open sky + intraoral incisions	Craniocerebral injury: 5 Cerebrospinal fluid leakage: 2 Diplopia: 3 Blindness or blurred vision: 2 Oculomotor paralysis: 1 Hypophasis: 1	None
ZMC, mandible and NOE	From bottom to top and from outside to inside: key points included proper positioning of the sphenozygomatic suture, zygomatic arch and zygomaticomaxillary sutures to reconstruct transverse and projection dimensions, and reduction and fixation of the condyles to reconstruct facial height. The NOE fracture was treated as above	The coronal + lower eyelid or transconjunctival + intraoral ± open sky + preauricular or retromandibular incisions	Craniocerebral injury: 6 Cerebrospinal fluid leakage: 1 Diplopia: 2 Blindness or blurred vision: 1 Facial nerve injury: 2 Oculomotor paralysis: 1 Hypophasis: 1	2 or 3 weeks
Frontal bone and/or frontal sinus, ZMC	The zygomaticomaxillary complex was reduced and fixed first. Then the naso-orbito ethmoid and frontal bone and/or frontal sinus fracture were reduced and stabilized	The coronal + lower eyelid or transconjunctival + intraoral ± open sky incisions	Craniocerebral injury: 7 Cerebrospinal fluid leakage: 3 Diplopia: 2 Blindness or blurred vision: 1	None
Frontal bone and/or frontal sinus, ZMC and mandible	Same as for the ZMC, mandible and NOE	The coronal + lower eyelid or transconjunctival + intraoral ± open sky + preauricular or retromandibular incisions	Craniocerebral injury: 5 Cerebrospinal fluid leakage: 2 Diplopia: 2 Blindness or blurred vision: 2 Facial nerve injury: 2 Oculomotor paralysis: 1 Hypophasis: 2	2 or 3 weeks

MMF, maxillomandibular fixation; ZMC, zygomatic maxillary complex; NOE, nasoethmoidal fractures.

Associated complications

Of 48 cases, 22 were complicated by craniocerebral injury, eight by hemorrhagic shock, eight by cerebrospinal fluid leakage, seven by diplopia, four by blindness or blurred vision, three by parotid duct rupture, six by facial nerve injury, two by occulomotor paralysis and two by hypophasis. Other traumas include fractures of the ribs, clavicle, scapula or cervical vertebrae (Table 2).

Discussion

Treatment procedure

Our analysis showed that restoration of both form and function should conform to principles of sequential surgical treatment for panfacial fractures, and that reconstruction can be simplified by a highly organized treatment sequence. Multiple sequences have been proposed for the repair of panfacial fractures (2, 6, 7). A range of potential methods may be effective in the management of panfacial injuries, depending on their severity and the materials available for repair. In addition, choice of plate and screw systems, repair methods, MMF use and bone transplantation can be critical choices.

In cases requiring restoration of both the occlusal relationship and the locational relationship of the maxilla and mandible, we propose that facial length, width and projection should be restored systematically using an outside-to-inside, bottom-to-top approach. In this case, accurate occlusal relation is central to reduction (10). For example, in the treatment of midface fractures with multiple or comminuted mandibular fractures, particularly with malunion of bone ends (e.g. the often-neglected sagittal fracture on the median palatine suture), reduction is difficult to perform because of the strong traction force applied to broken ends by surrounding muscles. Under these circumstances, repositioning should start from the lateral side. The position of the mandible should correspond to the position of the condyle and other landmarks of mandibular anatomy (11). The relationship between the maxilla and the mandible should then be determined by restoring the occlusal relationship. In this way, proper facial length is established in both upper and lower face regions (12). At the same time, facial width and projection must be restored using landmarks on the cranial base (13). Finally, soft tissue is considered the 'fourth dimension' of facial reconstruction. Bone reconstruction should be completed as soon as possible to minimize soft tissue shrinkage, stiffness and scarring in non-anatomic positions (14).

Significance of biological osteosynthesis in treatment of panfacial fractures

According to AO/ASIF principles, the goal of craniofacial fracture management is to achieve anatomic reduction, absolute stabilization, undisturbed healing, early painless functional exercise and restoration of overall configuration. This theory has become increasingly popular during the past 15 years for all types of maxillofacial fractures, including comminuted fractures. However, the incidences of non-union, breakage of internal fixation devices, poor wound healing, infection and delayed union remain high because of the stress shielding caused by rigid internal fixation, large dissection and diminished blood supply caused by strong reduction forces (15–17).

During the last two decades, the understanding of bone biology has evolved, leading to the recognition that preservation of bone fragment viability is key to unimpaired fracture healing. Two AO fundamental principles (18, 19) are stressed for obtaining adequate rigid internal fixation. First, fixation must support full, functional loads (load-bearing osteosynthesis). Second, absolute stability of the fracture construct must be achieved. Therefore, it is not possible to accommodate functional load in comminuted fractures through load-sharing osteosynthesis between the implant and the bone.

Importantly, BO is not at odds with the AO principles, but rather provides additional guidelines (8, 9). A central tenant of BO is that fracture treatment must take into account the biological characteristics of the affected bone. Minimally invasive osteosynthesis techniques are suitable for treatment of unstable panfacial fractures, especially in children and adolescents (20). Novel designs and applications of plates, locking screws and biocompatible titanium implants are among the techniques that reduce load borne by screws and plates (21). Efforts to improve stabilization seem to be important for the restoration of both form and function in panfacial fractures. One strategy involves use of an elastic blade plate to prevent atrophy of the bone cortex caused by stress shielding after plate placement (22). For example, in mandibular fractures, the use of limited contact plates (Limited Contact-Dynamic Compression Plate (LC-DCP), uni-Lock plates and lag screws) can protect the periosteal blood supply and bring about less osteoporosis than do contact dynamic compress plates. In addition, limited contact plates can induce formation of a thin callus on the cortex surface, which is of significance in the treatment of panfacial fractures in elderly patients and worthy of further investigation. Importantly, distal and proximal tissues of the fractured bone must be healthy so as to provide adequate mechanical support and blood supply, and to avoid plate rupture caused by excessive distortion stress (23).

Rigid fixation must be combined with elastic fixation. Examination of the 68 cases in this study revealed that internal rigid fixation cannot completely substitute for short-term intermaxillary traction. Because the causes of fractured malocclusion can be complex (22, 23), including variable type of fracture, degree of dislocation of the bone pieces and degree of disorganization of the postoperative stomatognathic system, a combined approach of rigid internal fixation and intermaxillary traction is beneficial for restoring stomatognathic function and healing of broken ends. For example, fracture of the zygomatic complex can result in limited ability to open the mouth because of obstruction due to dislocation of the zygoma and zygomatic arch from the coracoid process of the mandible. However, we also noticed that some complex zygomatic fractures observed in radiographs or CT images did not interfere with mandibular movement. The convulsion of the temporalis caused by impact of the bone pieces might be the cause of restricted ability to open the mouth. In these cases, malocclusion can be rectified through postoperative intermaxillary traction (24).

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