The Role of External Fixation in Trauma and Reconstruction of the Mandible in the Age of Rigid Fixation

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Abstract

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► mandible reconstruction
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► pediatric facial fractures

External fixation (ex-fix) is a method of closed fracture reduction that involves the use of pins to manipulate loose segments of bone which are then fixated by external connections. The first record of an ex-fix used for facial fractures was in World War II, when it was applied to stabilize a comminuted mandibular fracture. The popularity of ex-fix to treat facial fractures expanded until the 1960s, at which time rigid internal fixation started to become more common. Internal fixation was thought to result in better fracture immobilization, faster healing, as well as the benefit of avoiding external hardware for several weeks. Today, internal rigid fixation is essentially the gold-standard treatment for facial fractures, but there are some specific cases that are more amenable to external fixation (ex-fix) application. Herein, we discuss advantages and disadvantages to ex-fix in the modern treatment of comminuted mandible fractures, infected mandible fractures, fractures of the condylar region, oncologic mandibular resection, pediatric mandible fractures, and fractures in the edentulous patient.

Types of External Fixation

Many different types of ex-fix exist. One of the oldest is the modified Roger Anderson device which consists of percutaneous pins placed on either side of a fracture linked together by metal bars and connectors. Another example is a Joe Hall Morris appliance, a temporary biphasic system that uses a
self-curing acrylic to create a lightweight system of rigid fixation until more permanent fixation can be applied.\(^1\) More recently, ex-fix systems developed for orthopaedic surgery, such as the Colles’ wrist external fixator and the metacarpal external fixator, have been applied to mandible fractures, though their use in the face is off-label.\(^3,4\) Most recently, several ex-fix systems currently in circulation have been designed specifically for craniofacial use (\(\sim\)Fig. 1).

**Surgical Technique**

**Initial Considerations**

Exact surgical techniques vary based on fracture location but the general principles are universal. First, it is preferable to place percutaneous pins into “safe zones” of the mandible which avoid tooth roots, developing teeth, the inferior alveolar canal, the facial artery and vein, and the retromandibular vein (\(\sim\)Fig. 2). Safe zones are located along the inferior and posterior borders of the mandibular symphysis, body, and ramus. However, if the ex-fix is being used for temporary and intraoperative fixation, it can be placed superior to where the plate and screws will be placed near the external oblique ridge (\(\sim\)Fig. 3). Pins need to be placed inferior to tooth roots, which are generally twice the height of the tooth crown. For pins, placed in the subcondylar region of the mandible, it is important to take into consideration the path of the facial nerve trunk, as it crosses superficial to the mandible in the parotid tissue. Similarly, the location of the inferior alveolar nerve limits the vertical height of the safe zone in the mandibular body and angle, especially if the patient has an atrophic or edentulous mandible. In the parasympyseal area, it is best to avoid the mental foramen.\(^1\) To avoid potential injury to the inferior alveolar nerve, one can consider placing the pins medial to the mental foramen (closer to midline) in the parasympysis and along the mandibular angle.

In general, one or two self-tapping pins can be placed on either side of a fracture for appropriate stabilization. Whenever possible, two pins should be used to stabilize a bone segment if it is being used for a long-term treatment period as it is significantly more stable than one pin (\(\sim\)Fig. 4A–D).

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**Fig. 1** Craniofacial ex-fix set showing (A) different length pins with varying thread depths, (B) rods for connecting the pins, (C) connectors to secure the pin to the rod, and (D) connectors to secure adjacent rods. ex-fix, external fixator.

**Fig. 2** Safe zones of the mandible. The dark green regions located along the condylar head and along the posterior and inferior border of the mandible are safest for long-term ex-fix. However, the light green located at the external oblique ridge along the angle or ramus posterior to the third molar is also safe for short-term, intraoperative ex-fix. ex-fix, external fixator.

**Fig. 3** Placement of ex-fix prior to segmental mandibulectomy. Red lines mark the planned osteotomy while the yellow lines are the expected course of the inferior alveolar nerve. ex-fix, external fixator.
However, if the ex-fix is being used for intraoperative period only or for a short-time period, one pin in each bone segment may suffice (Fig. 5A, B). Several authors recommend using two pins on each side of condylar fractures to prevent rotation of the bony fragments; two-pin placement in the condylar head segment will likely require a wrist-fixator ex-fix which utilizes thinner diameter pins.\(^1\)

Outside the condylar region, pins are generally separated by 25 mm, though good stability can still be achieved if the pins are closer. Pins should be placed sufficiently away from the fracture lines, ideally at least 10 mm. Thicker pins are preferred, as they are less likely to loosen over time. Pins have different thread depths, and the appropriate depth is selected based on the bone thickness. Excessively long

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Fig. 4  Long-term ex-fix for comminuted bone fracture (marked with red box). (A) Yellow line represents the inferior alveolar nerve. Two pins placed into each bone segment offer superior stability and may be used to achieve bony union. (B) Long-term ex-fix for comminuted bone fracture (marked with red box). A rod is used to secure the two pins placed into each segment to achieve stability within each subunit. (C) Long-term ex-fix for comminuted bone fracture (marked with red box). Additional rods (rods at the periphery) are used to connect the different subunits in the final construct. (D) Instead of using additional rods to connect adjacent subunits, as seen in C, a single curved rod can be used to connect all the ex-fix connectors. ex-fix, external fixator.
threads can be troublesome in thin mandible segments, potentially causing inadvertent neurovascular injury. Moreover, the length of the pins will determine how far from the bone the pins will extend through the facial skin.

**Surgical Pin and Connector Placement**

After it is decided where the pins are going to be placed, a small cutaneous stab incision is made followed by blunt, soft tissue dissection to the bony surface to allow for placement of a drill or self-drilling pins. Generally, a trocar is used to protect the skin and subcutaneous tissue from injury. With self-tapping pins, use of drill speeds higher than 500 rotations per minute can result in heat-induced bone necrosis. Orienting the pins, 70 degrees from the bony surface in opposing fashion, helps to maximize pin retention. Once the pins have been placed, they are connected externally. External connectors are placed far enough away from the skin surface to allow for expected soft tissue edema, but not so far that it is cumbersome for the patient. When being used for closed reduction of multiple fractured segments, the pins can be interlinked between each bone segments to create a larger unit with greater stabilization. Another option is to use a single curved rod to stabilize all the bone segments. Evaluation of the contact between the fractured surfaces, as well as dental occlusion is used to determine if pin placement and fracture reduction is appropriate. While the fractured surfaces are not directly visible, contact between fractured segments can be determined through manual palpation and manipulation of bony fragments or via intraoperative radiologic imaging. Only after the reduction is confirmed, the fixation device can be tightened. If using biphasic pin fixation, the pins are covered with silicone tubing (such as an endotracheal tube) which is then injected with a self-curing acrylic that, when hardened, creates a lightweight, yet customizable, rigid device.

**Device Removal**

The ex-fix is left in place for several weeks to allow bony healing. During this time, healing progress can be evaluated via serial radiographs or computed tomography (CT). A panorex is preferable, as CT has been shown to be relatively inaccurate and lacking comparable sensitivity in detecting early callus formation and bony fusion. This is in part due to significant imaging scatter created by the device and dental artifacts. Recently, Avery et al evaluated transcutaneous ultrasound for early detection of bony healing and noted that echogenic foci visualized within the fracture gap correlate with callus maturation. Furthermore, ultrasound was able to confirm callus formation 4 to 6 weeks earlier than serial radiographs or CT scans, which may help to decrease the required duration of ex-fix placement while avoiding premature removal.

After adequate healing has taken place, the ex-fix can be removed, often in clinic with only local anesthesia. If biphasic pin fixation was used, it is helpful to cut the hardened acrylic between each pin prior to removal. Usually this can be done as early as 2 weeks after placement for a condylar fracture. However, the duration of ex-fix can be significantly longer if it is being used for other indications, such as chronic infections requiring prolonged antibiotic treatment, or if it is used to achieve bony union without internal rigid fixation.

**Clinical Indications**

**Temporary Stabilization**

Full-thickness mandibular bony defects may occur as a result of segmental mandibulectomy for malignancy, chronic infection, or osteoradionecrosis that failed to improve despite debridement and conservative therapy. Currently, large mandible defects (6 cm or longer) or anterior mandibular defects (medial to the mental foramen) are commonly addressed using microvascular osseous free flap transfer. Although there is a variation on what plate is used to secure the bony free flap, the senior authors (T.L. and Y.D.) generally use a load bearing, reconstruction plate to secure the free flap to remaining native mandible segments which is in line with craniofacial plating principles. The challenge with a case that requires segmental mandibulectomy is that once mandibular
continuity is disrupted, the disconnected segments will shift out of alignment, making it difficult to achieve premorbid occlusion. Ex-fix, that is applied prior to performing the segmental mandibulectomy, can help to stabilize the bone segments and maintain their natural position until a reconstruction plate can be applied (►Fig. 6A–E). During the ablative surgery, ex-fix pins are placed into the mandible away from the resection margin. The pins may be placed in an oblique fashion near the angle of mandible to incorporate more bone for increased stability and the rods and the final construct should point away from the neck dissection and the cancer resection margin (►Fig. 7A, B). Having the ex-fix device cephalically oriented will optimize exposure for the ablative surgeon when performing the tumor resection and neck dissection. Interestingly, Ung et al recommends a caudal orientation for ex-fix placement.10 However, the senior authors (T.L. and Y.D.) feel that placing the ex-fix device along the inferior aspect of the mandible can provide enough stability. The number of rods needed to stabilize the bone fragments can be increased if more space is needed for proper exposure.

We have found that using temporary, intraoperative ex-fix provides consistent premorbid occlusion and improves surgical efficiency by avoiding the need for maxillomandibular fixation (MMF). However, if the ex-fix device becomes loose during resection, it is best to use MMF to reestablish premorbid occlusion if there are teeth remaining.

**Condylar Fractures**

Fractures of the condyle represent 20 to 35% of all mandible fractures, and can result in long-term complications including malocclusion, reduced posterior facial height, trismus, chronic pain, and facial asymmetry.5,11 Multiple techniques for treating condylar fractures exist, and the surgical indications for open reduction and internal fixation (ORIF) are a point of ongoing controversy and debate in literature. Ex-fix has been used as a sole treatment option without rigid fixation for isolated condylar fractures with clinical success.

Zide and Kent first established absolute and relative indications for surgical management of condylar fractures in 1983 (∗Table 1).12 The results from elastic MMF have failed to provide consistent restoration of function, subsequently, leading to greater adoption of ORIF for subcondylar fracture treatment.11,13 The senior authors (T.L. and Y.D.) typically prefer to perform ORIF of minimally displaced subcondylar fractures with a four-hole miniplate and two monocortical locking screws in either side of the fracture, approached intraorally and endoscopic assisted. More severely displaced subcondylar fractures are approached using a submandibular incision near the angle of the mandible or by using a preauricular incision with facial nerve dissection.

Fig. 6 (A) Segmental mandibulectomy is performed after placement of ex-fix to maintain premorbid occlusion and bilateral mandible segments’ alignment. (B) Placement of a reconstruction plate to connect remaining mandible segments. (C) Removal of ex-fix after placement of reconstruction plate. (D) If a fibula flap is being used, the reconstruction plate is bent to a trapezoid shape to accommodate the linear bony contour, increasing bone and plane contact. Colored shapes represent a typical fibula bone flap with two bone segments. (E) Basal view of the trapezoid shape of the reconstruction plate. Colored shapes represent a typical fibula bone flap with two bone segments. ex-fix, external fixator.
Although ORIF remains one of the common treatment options, ex-fix has been used to manage condylar and subcondylar fractures, as it offers some unique advantages over ORIF. First, ex-fix allows for minimal movement of reduced bone fragments, thereby decreasing bone resorption seen with rigid internal fixation. Next, pin placement does not require the extensive subperiosteal dissection needed for plate application in ORIF. In addition, ex-fix pins that are placed into a condylar head segment that is severely tele-scoped medially can be more easily reduced. Finally, ex-fix devices and pin positions can be modified postoperatively if additional changes are desired to further optimize bony reduction (Fig. 8A, B).

Ex-fix management of condylar fractures can lead to successful outcomes comparable to ORIF. For this indication, ex-fix device is applied for approximately 2 weeks and is removed in office. 5,8,11 In a retrospective review by Cascone et al, 44 patients with 53 condyle fractures were treated with ex-fix alone through a preauricular approach. All patients recovered their premorbid occlusion after surgery, and at 12 months, 91% reported no pain, while 87% reported no temporomandibular joint (TMJ) dysfunction. Mouth opening was found to be >30 mm in 92% of patients. 5 Similarly, Iannetti and Cascone treated 22 patients with 34 condylar fractures with ex-fix using a preauricular approach. While one patient required repositioning of the fractured segment postoperatively, all patients experienced a return to premorbid occlusion without any complications or permanent facial nerve injury. 8 In 2015, Belli et al reported on the use of endoscopic assisted ex-fix of condylar fractures on 32 patients. Twenty-eight patients had optimal results without needing TMJ immobilization or transcutaneous access. However, five patients required revision surgery using a preauricular approach due to functional impediment in lateral movements as a result of inadequate repositioning of the fractured segments. 11 Overall, ex-fix as a single-modality treatment of subcondylar fractures offer similar clinical results to that of ORIF but with a decreased amount of subperiosteal dissection and risk of devascularization of the condylar head.

However, there are several disadvantages to ex-fix management of condylar fractures to consider. A transcutaneous pin placement carries the risk of poor aesthetic outcome and

Table 1 Zide and Kent indications for ORIF condylar fractures

<table>
<thead>
<tr>
<th>Absolute indications</th>
<th>Relative indications</th>
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<tbody>
<tr>
<td>Displacement into middle cranial fossa</td>
<td>Bilateral condylar fractures in an edentulous patient without a splint</td>
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<tr>
<td>Impossibility of obtaining adequate occlusion by closed reduction</td>
<td>Unilateral or bilateral condylar fractures where splinting cannot be accomplished for medical reasons or because physiotherapy is impossible</td>
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<tr>
<td>Lateral extracapsular displacement</td>
<td>Bilateral condylar fractures with comminuted midfacial fractures, prognathism or retragnathism</td>
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<tr>
<td>Invasion by foreign body</td>
<td>Periodontal problems</td>
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<tr>
<td>Loss of teeth</td>
<td>Loss of teeth</td>
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<tr>
<td>Unilateral condylar fracture with unstable base</td>
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Abbreviation: ORIF, open reduction and internal fixation.
Note: Adapted from Zide and Kent. 17

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prior to permanent reconstructive options (patients undergo multiple debridements of nonviable bone
rary measure to keep the bone segments in alignment while the outer rod stabilizes across the fracture. (B) Another option for ex-fix application for a condylar fracture (red line) is to use a single rod to stabilize all the pins across the subcondylar fracture site. ex-fix, external fixator.

Comminuted Fractures
A comminuted fracture usually results in significant damage to the periosteum, muscle, and mucosa, which disturb the vascular supply needed for bony healing. Unlike open reductions, which require additional periosteal stripping for hardware placement, a closed reduction obviates further vascular compromise of bone fragments. Comminuted fractures may be managed in a closed fashion with a combination of MMF and prolonged ex-fix (or only ex-fix for edentulous patients) to achieve bony union.

Infected Fractures, Osteonecrosis, Osteomyelitis
Infected fractures are difficult to manage, as any hardware may allow biofilm formation that can be resistant to intravenous antibiotics and a nidus for infection. This can be a troubling problem if it occurs in conjunction with osteoradionecrosis, comminution, or in an edentulous mandible. Ex-fix can obviate the need for large incisions and extensive soft tissue dissection in an infected, radiated field that risks vascular compromise of the overlying facial skin flaps. It can be utilized as a temporary measure of fixation, while the infection is being controlled and until rigid internal fixation can be performed.

The senior author (Y.D.) has successfully used ex-fix to provide temporary fixation prior to a staged final reconstruction in a patient with a chronically draining fistula from atypical
tuberculosis. Atypical tuberculosis presents a unique challenge, as it can cause a troubling skin fistula that can take months of antibiotics therapy for it to heal. Ex-fix in this setting provides temporary fixation of the mandible to prevent further scar contraction around the bone and to prevent undesirable displacement of the ramus/condyle segment.

Except for atypical infections, such as tuberculosis, which can be difficult to manage acutely, ex-fix may play a limited role as a sole treatment of the infected mandible and may be more useful as an adjunct to aggressive bone and soft tissue debridement prior to definitive reconstruction.

**Special Considerations**

**Pediatric Fractures**
The management of facial fractures, in particular condyle fractures, is more complicated in pediatric patients. Because the condyle is important in the growth of the jaw in children, improper management of condylar fractures can result in ankylosis, trismus, malocclusion, and growth disturbances. Currently, the mainstay of management in pediatric mandible fractures is closed treatment, but surgical intervention with ORIF involving moderate to severely displaced fractures is becoming more popular. Conversely, as the role of surgical intervention for condyle fractures in the pediatric population has increased, the discussion on the potential negative impact of internal fixation on pediatric dentition and growth of the mandible has also increased.

Cascone et al evaluated the use of ex-fix for pediatric condylar fractures in 21 patients aged from 6 to 17 years. All patients underwent ex-fix application using a preauricular approach without ORIF for approximately 2 weeks with subsequent removal in office. All patients achieved appropriate reduction of the condyle and the interincisor distance increased from 17.9 mm to greater than 35 mm postoperatively, without any complications at 12-month follow-up. Moreover, the maximal lateral excursion increased from 4.4 to 10.1 mm on the ipsilateral side of the fracture and 4.8 to 10.6 mm on the contralateral side. While three patients did have temporary weakness of the facial nerve during the first few weeks postoperatively, they all achieved complete recovery. The authors concluded that ex-fix is beneficial in the pediatric population, as it requires limited dissection, decreases the amount of scar formation or fibrosis, and, thus, minimally interferes with skeletal growth.

**Edentulous Mandible**
The use of ex-fix can be helpful in edentulous mandible patients, as MMF cannot be applied. In addition, given the lack of available bone height along the lateral border, there is an increased difficulty in plate and screw placement from poor bone stock to hold the screws. Because of the limited room available for screw placement, the inferior alveolar nerve is at a high risk of injury. For those fractures that are amenable to plating, the plates placed along the lateral cortex may often interfere with denture placement. Ex-fix alone has been used successfully in treating edentulous or atrophic mandible patients. Because the application of ex-fix takes minimal time, it is a viable option for temporary fixation in patients who cannot tolerate a long general anesthetic. In patients with a severe atrophic mandible where it will be difficult to place screws without injuring the inferior alveolar nerve, ex-fix may be an effective treatment modality, though it requires patients who can tolerate prolonged application of the device.

Interestingly, Wood et al described his method of using a locking miniplate with bicortical screws intraorally on top of the mucosa, similar to ex-fix but using traditional ORIF hardware with a locking system. The bicortical locking screws are placed along the mandibular angle and medial to the mental foramen to minimize the risk of inferior alveolar nerve injury. These bicortical locking screws behave as miniature ex-fix pins and are stabilized to a locking plate, similar to the interconnecting rod. The locking plate is left intraorally, superficial to the mandible mucosa, resulting in no need for subperiosteal dissection. All patients, in their study, resumed a soft diet the first postoperative day, and all eventually achieved bony union. Further, there were no major complications in any patients.

The use of ex-fix is not without its drawbacks. The apparatus can be bulky and can have a negative aesthetic appearance during the treatment period that can last several weeks to several months depending on the clinical situation. When ex-fix is being used during temporary, intraoperative stabilization, the ex-fix device can be physically obstructive to oncolologic resection surgery if not applied correctly. Also, the ex-fix device can loosen during surgery, causing the occlusal plane to drift and loss maintenance of occlusion. In such situation, ex-fix is no longer effective and instead using MMF to reestablish a proper occlusal plane is advised prior to a reconstruction plate placement.

The modern applications of ex-fix are largely limited to severe, complicated cases, and, as such, can be associated with a high rate of complications. When used for comminuted mandible fractures, Ellis et al found 23.5% of patients treated with ex-fix developed nonunion requiring bone grafts, while 11.7% of patients treated with ex-fix developed malocclusion (an overall complication rate of 35%). Rates of nonunion and malocclusion were much higher with ex-fix treatment than with rigid internal fixation. However, when used for the management of condyle fractures, Cascone et al found the procedure to be generally well tolerated. In the immediate postoperative period, less than 7% of patients reported temporary, partial facial nerve weakness that resolved without intervention in a few weeks. At 12-month follow-up, only 4.5% of patients reported recurrent TMJ disorder. One patient developed a hypertrophic preauricular scar which led to patient dissatisfaction. No patients had systemic infection, and less than 3% of patients developed surgical site infections treated successfully with antibiotics.
**Conclusion**

Ex-fix use has declined since the advent of rigid internal fixation, but it continues to play a critical role in the management of complex mandible fractures in a specific subset of patients. From its role in the management of condyle fractures or pediatric mandible fractures to intraoperative, temporary stabilization of the mandible during segmental mandibulectomy, ex-fix has proven to be an effective treatment and should remain a part of the treatment armamentarium employed to optimally manage facial fractures.

**Conflicts of Interest**

None.

**References**