Recent advances in fixation of the craniomaxillofacial skeleton

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Purpose of review
Fixation of the craniomaxillofacial skeleton is an evolving aspect for facial plastic, oral and maxillofacial, and plastic surgery. This review looks at the recent advances that aid in reduction and fixation of the craniomaxillofacial skeleton.

Recent findings
More surgeons are using resorbable plates for craniomaxillofacial fixation. A single miniplate on the inferior border of the mandible may be sufficient to reduce and fixate an angle fracture. Percutaneous K-wires may assist in plating angle fractures. Intraoperative computed tomography (CT) may prove to be useful for assessing reduction and fixation.

Summary
Resorbable plates are becoming increasingly popular in orthognathic surgery and facial trauma surgery. There are newer operative techniques for fixating the angle of the mandible. Also, the utilization of the intraoperative CT provides immediate feedback for accurate reduction and fixation. Prebent surgical plates save operative time, decrease errors, and provide more accurate fixation.

Keywords
craniomaxillofacial fixation, resorbable plates, reduction

INTRODUCTION

Craniomaxillofacial fixation has evolved significantly over the past 200 years. Schede is credited with the first application of rigid internal fixation to the facial skeleton; he described the use of steel plates and screws to fixate mandible fractures in 1888 [1]. The application of rigid fixation did not become popular in North America until the 1970s, because of the development of corrosion-resistant and biocompatible metals and materials [2,3]. Prior to the use of Titaninum, several other metal alloys were applied for rigid internal fixation. Consequently, these metal alloys, which included stainless steel, Vitallium, Copper, and so on, have fallen out of favour because of their corrosion profile and/or lack of inertness [4,5]. Also, Vitallium has a higher scatter profile than Titanium on computed tomography (CT) scans and costs much more to manufacture [6–8]. Titanium also has the ability to osteointegrate, that is, bind to bone [9]. Unfortunately, there are risks of using Titanium plates for rigid fixation. Although it is the most widely used metal today for rigid fixation of the craniomaxillofacial skeleton, there are associated complications. Previous studies have confirmed toxicity and hypersensitivity reactions [10–12]. Although these reactions are rare, the metal implants are usually removed because of infection, exposure, pain, and discomfort. Past studies have estimated that up to 10–12% of metal implants in the craniomaxillofacial skeleton are removed [13,14]. In recent years, resorbable plates have become more popular, as they allow stabilization and fixation but are not permanent. These plates are used extensively in the pediatric population, as permanent fixation may hinder growth in this group. Also, the use of resorbable plates continues to expand in the adult population.

Technological advances in intraoperative CT, better plating systems, other recent new items of surgical instrumentation, and operative techniques

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KEY POINTS

- Resorbable plates are becoming increasingly popular in orthognathic and facial trauma surgery.
- Newer operative techniques are described to aid in plating angle fractures and approaches to subcondylar fractures.
- Intraoperative CT provides accurate assessment of reduction and fixation and should be utilized more often in complex cases.

have improved the ability to adequately reduce and fixate facial fractures and osteotomies. This review highlights the latest developments in fixation of the craniomaxillofacial skeleton.

PLATING SYSTEMS

No new plating systems have been recently introduced. The newest technologies in craniomaxillofacial fixation are the various locking plates and screws. These systems allow the screw to lock into the plate, so the screw can depend more on the plate for stability rather than the mandible. In addition, more resorbable plating systems are being evaluated, especially for the adult population. A recent study by Turvey *et al.* [15■■] reviewed over 761 operations using biodegradable plating systems and found them to be reliable. The author reported a 1–2% failure rate of the screws and no failure of the plates themselves [15■■]. He reported that, in 14 procedures, either there was screw loosening or the bone fractured around the screws; 4% of the implants needed to be removed because of immunologic reactivity [15■■]. In 31 patients, the plates had to be removed due to inflammation [15■■]. Severe inflammation occurred in either the maxilla or the orbit, not in the mandible. Turvey reported a 6% overall failure rate with the resorbable systems, which is comparable to titanium plates. When comparing orthognathic surgery, Schmidt reported a 10% failure rate when titanium plates and screws were used [14]. In addition, patients with titanium plates complained of pain, discomfort, thermal sensitivity, and infection even after 20 years postplacement, whereas patients with poly-L/DL-lactic acid, PLLDL, had no complaints after 20 months [15■■].

However, some of the drawbacks of using resorbable plating systems include cost and increased operating room time. The system used by Turvey required the screw holes to be drilled and tapped, and then the screws had to be screwed into the plates. This would increase overall operating room time and increase surgeon fatigue. Currently, several titanium plating systems have self-drilling screws that do not require a predrilled hole. Not only does this feature save time, but it also avoids risk to surrounding tissue, and decreases bleeding, thermal bone injury, and nerve damage. Also, the study by Turvey focused on craniomaxillofacial surgery, especially orthognathic, with limited data on mandible fractures [15■■].

While using resorbable plates, Kim and Kim [16■■] reported using the tapping driver not only to tap the drill hole, but to hold the plate in place while drilling. The driver acts as a metal screw while the other holes are being drilled [16■■]. This step saves time, as the tapping driver holds the plate in place and prevents the plate from shifting while drilling the other holes (Fig. 1). The authors used this method on 106 facial fractures and achieved excellent results. They did not report any complications. None of the patients in their study developed any acute infections or inflammation. Patients were satisfied with their results and there were no complaints of palpable hardware or a foreign body sensation [16■■]. Kim and Kim [16■■] also used absorbable plates for mandible fractures ($n = 7$). Despite the low number of patients, the surgeons did not have any complications and reported accurate reduction and fixation. Previous studies have remarked on the strength and durability of resorbable plates, but a majority of these studies focus on orthognathic surgery. Kim and Kim presented data focusing on trauma/fractures, and their study reinforces the reliability of the resorbable plating system in craniomaxillofacial trauma.

The Cochrane Collaboration published a review comparing resorbable versus titanium plates for facial fractures in 2009 [17]. The reviewers could not find any randomized controlled studies to fulfill the requirements to complete an official review. The authors did mention that several randomized trials were aborted. This finding might suggest that resorbable plates may not be as reliable as the titanium plating system in repairing facial fractures. However, a few studies listed in the Cochrane Collaboration remarked on the safety and reliability of resorbable systems in orthognathic surgery. For instance, Hochuli-Vieira *et al.* [18] determined that resorbable fixation systems were comparable to titanium plates and screws. Also, Cheung *et al.* [19] reported that resorbable plates did not cause any increased morbidity.

NEW OPERATIVE TECHNIQUES

When plating unstable fractures of the mandible angle, several surgeons experience difficulty with placing an inferiorly positioned plate. The plate

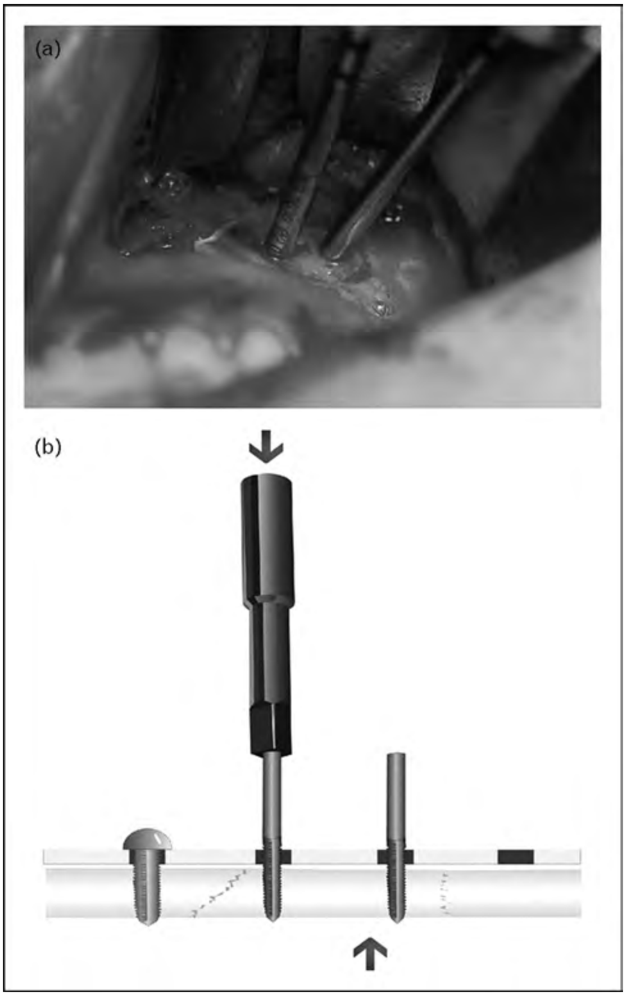

FIGURE 1. The tapper inserted to hold the plate in place while a new drill hole is placed. The top photo (a) shows an intraoperative view of the tapper preventing the resorbable plate from moving while the drill is engaged. The bottom photo (b) illustrates the concept behind using the tapper to hold the resorbable plate when placing a new hole. Reprinted with permission from [16■■].

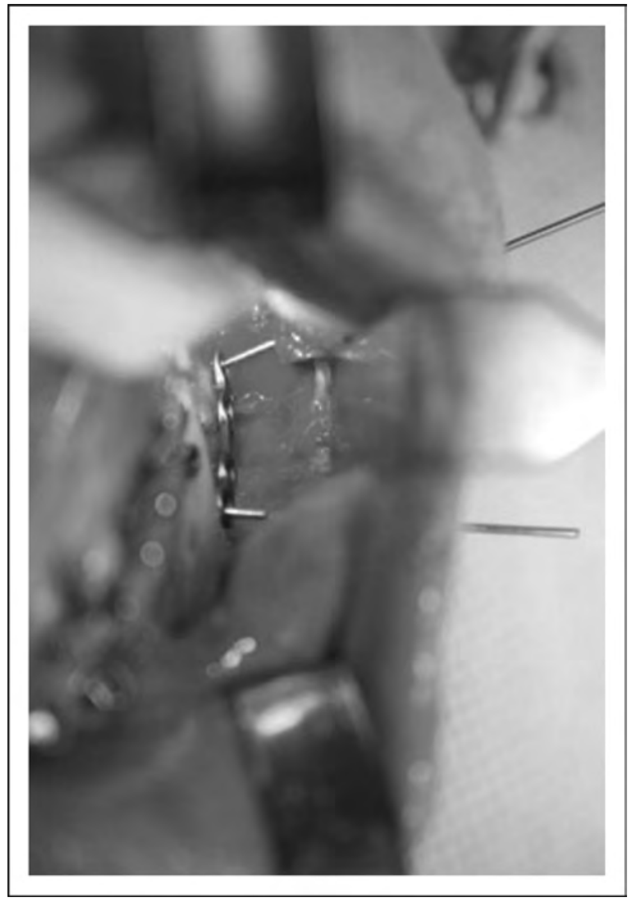

FIGURE 2. An intraoperative view of percutaneously placed K-wires holding the inferior border tension band in an angle fracture. Reprinted with permission from [20■].

shifts during the percutaneous placement, which makes application quite difficult. Perry *et al.* [20■] describe a technique using K-wires to hold the plate in place percutaneously prior to drilling and placing the screws (Fig. 2). The K-wires prevent the plate from migrating in the wound while maneuvering the percutaneous drill guide and drilling the screw holes. This technique may save time and frustration while placing an inferior plate in a mandible angle fracture. Perry *et al.* [20■] noted good results with this technique and no complications; however, they did have a small sample size ($n = 9$).

Angle fractures are always a topic of controversy in craniomaxillofacial surgery. The site has one of the highest complication rates. No consensus exists as to the best approach to accurately reduce and fixate an angle fracture to obtain the lowest risk of complications. Several techniques have been described and argued to be the best method to treat a fracture of the mandible angle. Potter and Ellis [21] reported that a single 2.0 mm miniplate was associated with the fewest major complications. However, other authors have challenged this study and felt that a more rigid fixation is necessary than a single monocortical miniplate along the oblique ridge of the angle of the mandible. A recent article published by Singh *et al.* [22■] describes a new technique to fixate a displaced angle fracture. The authors describe using a single miniplate at the inferior border of the mandible. The technique involves an open approach with a Risdon incision to access the angle. All the patients were placed in maxillomandibular fixation (MMF) to reduce the fracture. A 2.0 mm miniplate was then placed and two bicortical screws were set on each side of the fracture site. Elastic MMF was used on each patient, and subsequently removed after 7 days, along with the arch bars [22■]. Overall, good results were obtained from the patient sample size of 56. Singh *et al.* [22■] reported a minor complication rate of 9.5% (occlusal disturbances, local infection, or temporary facial paresis). All the complications resolved with conservative management, except in one patient who developed an infection of a devitalized tooth, which required extraction, incision and drainage, and antibiotics [22■].

Another area of controversy in mandibular trauma includes subcondylar fractures. These types of fractures are the most common and some of the most difficult to adequately reduce and fixate due to the proximity of the facial nerve [23,24]. Several open techniques are described and can be quite difficult to execute, especially with a dislocation of the condylar head from the mandibular fossa. Recently, Sugamata *et al.* [25■] presented a surgical method to reduce a displaced condylar head using a new retractor. The retractor allows the surgeon increased visualization and access to reduce a severely displaced condylar head (Fig. 3). Sugamata *et al.* access the condylar fossa using a retromandibular (transparotid) approach. Once the condylar fossa is exposed, the retractor is placed between the fractured end of the condylar process and the lateral margin of the mandibular fossa and expanded to allow the surgeon to reduce the fractured condylar head (Fig. 4). After reduction with forceps to grasp the condylar head, the fractured condyle is plated with miniplates and the wound is closed. The patients are placed in MMF, and 24 h later changed to elastic MMF for 1 month [25■]. A total of eight patients underwent the operation with the new retractor and all had good occlusion; however, two had deviation of the mandible toward the affected side and one had a facial nerve paresis that resolved after 2 months. Sugamata *et al.* advocate the use of this retractor to increase exposure and allow reduction of a medially displaced condylar fracture under direct visualization [25■].

FIGURE 3. The new instrument to retract open the condylar fossa for added exposure and to aid in reduction and fixation of a subcondylar fracture. Reprinted with permission from [25■].

FIGURE 4. An anatomical image of the new retractor engaged in the condylar fossa. Reprinted with permission from [25■].

With regards to reduction, OsteoMed (Addison, Texas, USA) have developed new titanium plates that allow a surgeon to hold the fracture in proper reduction while placing the drill holes and screws (Fig. 5). The plate is designed to allow space for reduction forceps to assure reduction and keep the fracture reduced when drilling the screw holes.

INTRAOPERATIVE CT

Recently, craniomaxillofacial surgeons have been utilizing intraoperative CT as a guide for proper reduction and fixation. Rabie *et al.* changed the fixation of a few patients studied after utilizing intraoperative CT [26]. The intraoperative CT scanner allowed a 3D reconstruction and multiplanar analysis prior to completion of the case to assess reduction and fixation. If any changes need to be made, the fracture can be altered for proper correction [26]. The senior author (RMK) has been using intraoperative CT for assessing the position of

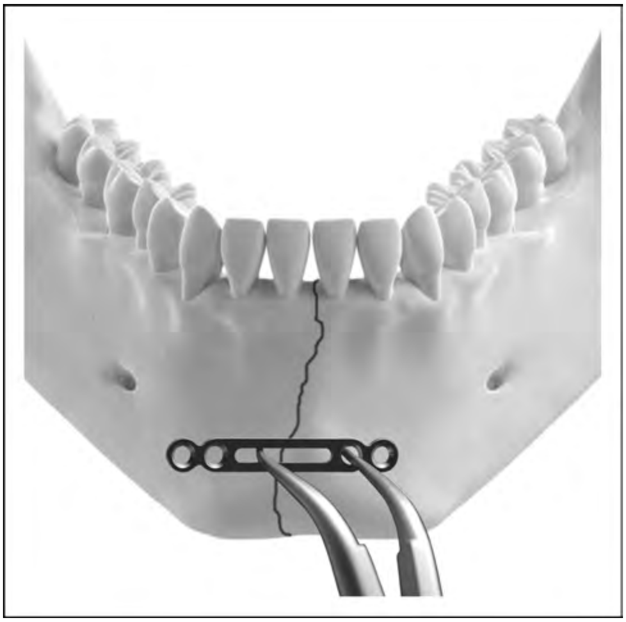

FIGURE 5. The new plate that allows reduction of a mandibular fracture while placing the screws, available through Osteomed.

orbital implants for severely displaced orbital fractures and has found it necessary to reposition implants as a result of the findings on the intraoperative CT scan.

PREBENT IMPLANTS

Several plating manufacturing companies have developed prebent plates for orbital floor fractures and mandibular reconstructions. The fractures or planned osteotomies are mapped out via 3D CT imaging and the proper titanium plates are developed. The anatomical 3D prebent plates were first piloted in cadavers with extreme accuracy, with mean implant error of less than 1 mm [27]. Prebent orbital plates based on cadaver models are available through plating companies, such as Synthes, Inc. (West Chester, Pennsylvania, USA) (Fig. 6). Also, Kozakiewicz *et al.* [28] describe good outcomes using customized prebent orbital floor reconstruction plates. The authors would send the CT scans per respective patient and the prebent orbital floor plate would be constructed to fill the contour of the fractured orbit [28]. All the patients ($n = 6$) achieved improved vision and resolution of their diplopia, if present.

In addition, prebent mandible plates are available for reconstructing mandibular defects. Customized mandibular plates save operating room time and are extremely reliable for reconstruction, have lower risks, and overall improved patient satisfaction [29]. In addition, if a prebent customized plate

FIGURE 6. Prebent orbital plates available from Synthes.

is lost, not produced in time, or defective, Synthes, Inc. (West Chester, Pennsylvania, USA) does have preformed mandible reconstruction plates based on data analysis from over 2000 CT scans that can be quite useful.

ENDOSCOPY IN CRANIOMAXILLOFACIAL SURGERY

Endoscopy is expanding in the fixation of the craniomaxillofacial skeleton. The endoscope is a popular approach for plating subcondylar fractures of the mandible. Over the past decade, the procedure has gained significant acceptance as a safe approach to reduce and fixate these fractures [30]. The endoscopic approach works best on noncomminuted fractures that can hold two screws in a plate [30].

In addition, the use of the endoscope for orbital floor repair remains controversial. However, the endoscope is gaining more acceptance for repair of medial orbital fractures. Ballin *et al.* describe a technique using the endoscope for transnasal access and an autogenous graft to repair medial orbital wall fractures [31]. The authors had great success with all 17 patients, except one, who had persistent diplopia [31]. Otherwise, the technique provides a well tolerated transnasal alternative for reducing and repairing a medial orbital fracture.

CONCLUSION

A few recent advances have occurred in fixation of the craniomaxillofacial skeleton. Craniomaxillofacial surgeons are presented with an increase in options for proper reduction and fixation, ranging from increased use of resorbable plates in the adult population, newer operative techniques for fixation, and the latest equipment for fracture reduction and fixation, to the use of intraoperative CT for assessment.

Acknowledgements

None.

Conflicts of interest

Dr Kellman is a speaker for Synthes Nursing Education.

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