Updates in Management of Craniomaxillofacial Gunshot Wounds and Reconstruction of the Mandible

Baber Khatib, MD, DDS[a,b,c,*], Savannah Gelesko, MD, DDS[c], Melissa Amundson, DDS[c,d], Allen Cheng, MD, DMD[c,d,e], Ashish Patel, MD, DDS[c,d,f], Tuan Bui, MD, DDS[g], Eric J. Dierks, MD, DMD[c,d], R. Bryan Bell, MD, DDS[c,d,f,h]

KEYWORDS

• Gunshot wounds • Mandible reconstruction • Facial trauma • Ballistic trauma • Virtual surgical planning • Computer-aided surgery

KEY POINTS

- Mandibular injuries have been treated effectively for generations using closed reduction and open reduction with internal fixation.
- With advances in computer-aided surgery, complex and difficult surgeries are now possible with the precision and accuracy once achieved by only a select few seasoned surgeons.
- The increasing research and applications of custom hardware, patient-specific planning, and virtual surgery has led to, and will continue to lead to, improved patient function, improved esthetics, decreased operative times, decreased costs, and most importantly beneficial patient outcomes.

INTRODUCTION

Mandibular injuries have been treated effectively for generations using closed reduction and open reduction with internal fixation. Recently, there have been several notable advances in surgical management that have added substantially to a facial surgeon's ability to tackle simple as well as complex mandibular injuries more effectively.

Recent hardware advances in closed reduction include maxillomandibular fixation (MMF) screws in lieu of arch bars and hybrid systems that combine traditional arch bars with screw fixation. Open reduction and fixation has seen some very

Disclosure statement: The authors have nothing to disclose.
[a] Advanced Craniomaxillofacial and Trauma Surgery/Head and Neck Oncologic and Microvascular Reconstructive Surgery, Department of Surgery, Legacy Emanuel Medical Center, 2801 N Gantentenbein Avenue, Portland, OR 97227, USA; [b] Providence Portland Hospital, 4805 NE Glisan Street, Portland, OR 97213, USA; [c] Head & Neck Surgical Associates, 1849 NW Kearney Street #302, Portland, OR 97209, USA; [d] Department of Surgery, Trauma Service, Legacy Emanuel Medical Center, 2801 N Gantentenbein Avenue, Portland, OR 97227, USA; [e] Head and Neck Cancer Program, Legacy Good Samaritan Medical Center, 1015 NW 22nd Avenue, Portland, OR 97210, USA; [f] Providence Oral, Head and Neck Cancer Program and Clinic, Providence Cancer Center, 4805 NE Glisan Street, Portland, OR 97213, USA; [g] Oral and Maxillofacial Pathology, Sanford Health, E - 1717 S University Drive Fargo, ND 58103, USA; [h] Robert W. Franz Cancer Research Center, Earle A. Chiles Research Institute at Providence Cancer Center, 4805 NE Glisan Street, Portland, OR 97213, USA
* Corresponding author. 1849 Northwest Kearney Street, #300, Portland, OR 97209.
E-mail address: baber.khatib@gmail.com

Facial Plast Surg Clin N Am 25 (2017) 563–576
http://dx.doi.org/10.1016/j.fsc.2017.06.007
1064-7406/17/

exciting applications of technology that include prebent and custom patient plates.

As a result of their complexity, treatment planning for facial ballistic injuries has seen an increase in the use of virtual surgery, patient-specific surgical guides, and intraoperative navigation and/or imaging to yield predictable and consistently repeatable results, once only achievable by seasoned surgeons.

The authors briefly review updates in management of mandibular trauma and reconstruction as they relate to MMF screws, custom hardware, virtual surgical planning (VSP), and protocols for use of computer-aided surgery and navigation when managing composite defects from gunshot injuries to the face.

Advances in Closed Reduction

MMF has a long history in the treatment of facial fractures dating back to 460 BC when Hippocrates used gold wire to fixate teeth for a mandible fracture.[1] Over the years there have been many modifications, including Barton bandage, suspension wires, Ivy loops, arch bars, MMF screws, and embrasure loops.[1–3] Erich arch bars (Karl Leibinger Co, Mulheim, Germany) continue to be the most commonly used technique. MMF screw fixation has the benefit of speedy application, decreased risk of puncture injury to the surgeon, less damage to the periodontium, and simple application and removal.[2,4–6] Their use is not without complications. The most commonly reported complications include screw loosening, iatrogenic damage to tooth roots, screw fracture, and ingestion.[7] A combination between MMF screws and arch bars known as *hybrid systems* are the newest advances to closed reduction. Commonly used systems include the SmartLock System Hybrid MMF (Stryker, Kalamazoo, MI), the MatrixWave (DePuy Synthes West Chester, PA), and the OmniMax MMF System (Zimmer Biomet, Jacksonville, FL). These systems are approved by the Food and Drug Administration for use in adults and children with fully erupted permanent dentition as a temporary means of fixation.[8–10] These systems allow expeditious placement associated with MMF screws while maintaining lugs at crown level, allowing traction vectors closer to the occlusal table. Potential complications are similar to those of MMF screws. Although the hybrid systems are much costlier than Erich arch bars, Kendrick and colleagues'[11] cost analysis of the Stryker SmartLock system versus traditional arch bars found no difference when accounting for operating room time, cost, and time saved.

Advances in Open Reduction

Virtual surgical planning/Stereolithography

Among the greatest technological advances in craniomaxillofacial (CMF) surgery is computer-aided CMF surgery. Bell[12] divides computer-aided CMF surgery into 3 main categories: (1) computer-aided presurgical planning, (2) intraoperative navigation, and (3) intraoperative computed tomography (CT)/MRI imaging. Computer-aided presurgical planning in mandibular trauma and reconstruction involves computer-aided design and computer-aided manufacturing (CAD/CAM) technology and VSP, which can then be applied to the fabrication of stereo-lithographic models and custom plates.[12–15]

Even in basic mandible fractures, intraoperative bending and contouring of reconstruction plates can be time consuming and inaccurate. Complex, multi-segment, and/or avulsed mandibular defects make this task much more difficult and potentially frustrating.

Although originally developed for industry, initial medical applications of CAD/CAM included neurosurgery and radiation therapy. CAD/CAM has since proven indispensable in the reconstruction of complex mandibular trauma and other CMF surgery.[16] CAD/CAM software enables the clinician to import 2-dimensional CT data in Digital Imaging and Communications in Medicine (DICOM) format to a computer workstation and to generate an accurate 3-dimensional (3D) representation of the skeletal and soft tissue anatomy. These digital models can be manipulated by virtual surgery allowing restoration of bony segments to their pretraumatic positions. Stereo-lithographic models of the virtually reduced mandible are then fabricated and can be used to manufacture custom cutting guides, plates, and splints.[12] These models have been reported to be accurate within 1 mm and have shown to decrease operative time and wound exposure time when used in the planning stage.[17,18]

Despite this degree of precision, there are a few areas where significant inaccuracies can be introduced. One critical area of inaccuracy is in the dental occlusion. CT scans, whether medical grade or cone beam, are unable to accurately capture occlusal anatomy. If accurate occlusal relationships are critical for surgical planning, then separate impressions must be taken from patients. These impressions can be done using traditional analog techniques with alginate/polyvinyl siloxane and stone or using newer digital impression techniques. Analog models are scanned into digital information. The dental and occlusal data can then be fused with the maxillofacial CT. Fusion can be